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ANNUAL 2021

THE WIRED WORLD IN 2021

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Contributors

Some of the innovators, writers and illustrators who helped make The WIRED World in 2021 possible

DAVID BAKER

–

"When The WIRED World in 2020 went to press in October 2019," says Baker, who has edited the magazine since its launch in 2012, "none of us had any sense of the catastrophe that would envelop the world just a few months later. But we humans are an adaptable species and, as many of our predictions for 2021 show, we're already working out how to respond. From smarter ways to work, to AI-based approaches to tackling disease, to more resilient and interconnected global politics, 2021 will demonstrate we're good at bouncing back from adversity."

JENNIFER DOUDNA

–

Co-winner of the 2020 Nobel Prize for Chemistry, Doudna predicts that, in 2021, "CRISPR gene editing will allow us to act more boldly in the face of interconnected issues."

NIGHAT DAD

–

"Freedom of expression online is declining globally," says Dad, a lawyer and internet activist. "This trend is set to continue in 2021, as social-media firms and governments co-operate."

CHI-CHI NWANOKU

–

The Chineke! Foundation founder writes that paying lip-service to diversity will need to end In 2021: "Organisations will realise that tackling racial injustice is a real-world, long-term project."

LEONIE BOS

–

"I try to link my illustrations when creating a series," says Bos of the Culture section. "The visual connections make them all relate – appropriate for a super-connected world."

KERSTI KALJULAID

–

"The online world has made borders redundant and this challenges the nature of nation states," writes the president of the Republic of Estonia. "In 2021, States will have to respond."

OBUM EKEKE

–

"In 2021, the science and technology sectors will stop looking for quick fixes to address under-representation," says Ekeke, DeepMind's leader on education partnerships.

HALEY TIPPMANN

–

"For the Business section, the underlying narrative was WFH and what happens next," says Tippmann. "I drew inspiration for the illustrations from my own environment and experiences."

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2021: a year defined by fundamental changes

The global pandemic has accelerated uptake of new technologies – and there's no going back

By **Greg Williams**

DURING THE EARLY DAYS OF THE CORONAVIRUS pandemic, there were various prognoses regarding the nature of a future economic recovery. Around April – perhaps buoyed by the way in which some Asian countries were beginning to rebound after having managed the public health crisis with relative success – many analysts in the west were talking about a V-shaped recovery: a precipitous decline followed by a sharp incline back to where economies had been at the beginning of 2020.

As the global economy struggled through the year, the idea of a V-shaped recovery was replaced by something resembling a K. Data from China in the autumn suggested that retail is back at pre-virus levels and exports are growing at double digits. However, it also demonstrated that the bottom 60 per cent of the population were poorer because of the crisis, whereas higher earners were benefiting – the result of government policy that supports employers rather than employees.

One well-worn truism of the crisis is that it's served to accelerate trends that were already underway – if you're working in cloud-based collaborative software for enterprises or developing healthcare imaging, then chances are that 2020 has exceeded your forecasts. If you're a highly leveraged airline or in commercial real-estate, it's likely not to have been a vintage year.

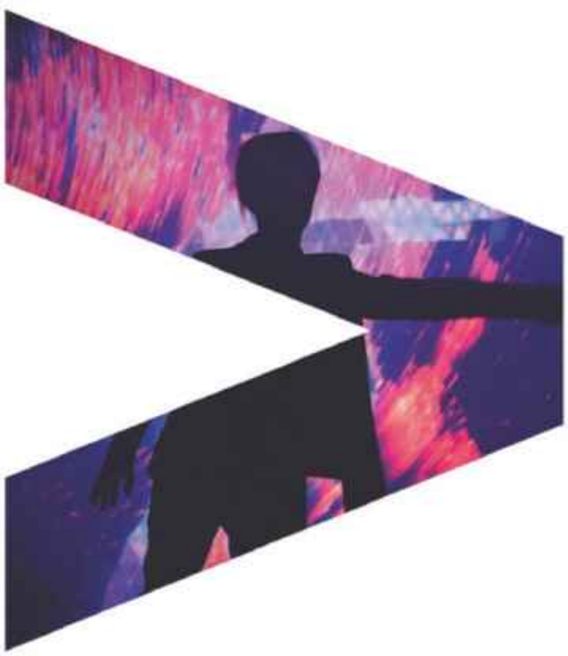
While it's tempting to think that some of the trends we're seeing are structural, many will prove to be cyclical. Sure, city centres might be impacted in the short-term, but the long-term trend is towards the growth of urban centres. On the other hand, the move to e-commerce, the uptake of contactless payments, the expansion of cloud-based services, the collision of biological science and technology and the transition from carbon energy to electric are all fundamental – and permanent – shifts that were stimulated by the coronavirus crisis.

These are structural changes that are allied to other impact-driven trends that are occurring both within organisations and more broadly within society: a drive towards diversity and inclusion, sustainable consumption, the need to halt humanity's assault on nature and a growing awareness of the deep structural inequalities in advanced economies.

Every year we ask some of the world's smartest thinkers to make a prediction about the 12 months to come. It's never an easy task and is made even harder than usual this year by the extraordinary events of the past few months. What's noticeable, though, is the reassuring vision that our contributors have – throughout the issue there are bold forward-looking ideas that will benefit humankind and the planet. While 2021 will require fortitude and resilience, there is much to inspire and encourage us – and WIRED will continue to champion the people, organisations and big ideas driving positive change in the world.

Greg Williams is the editor of WIRED

Right: urban centres won't wither away – but they will be reinvented



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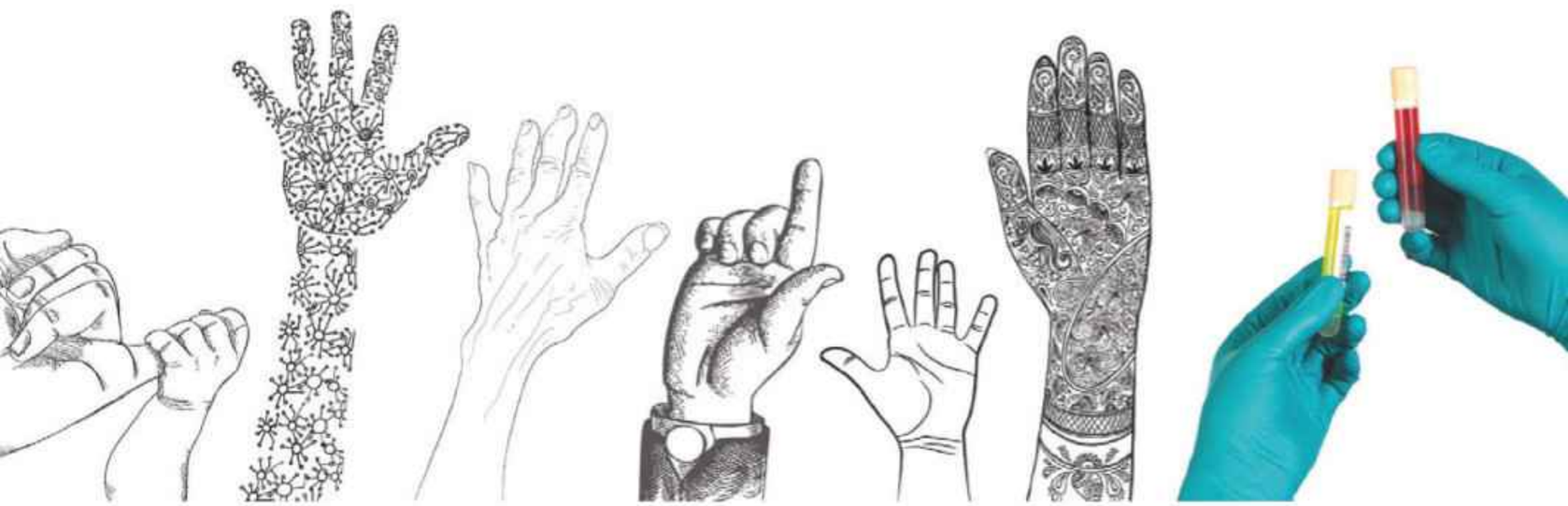

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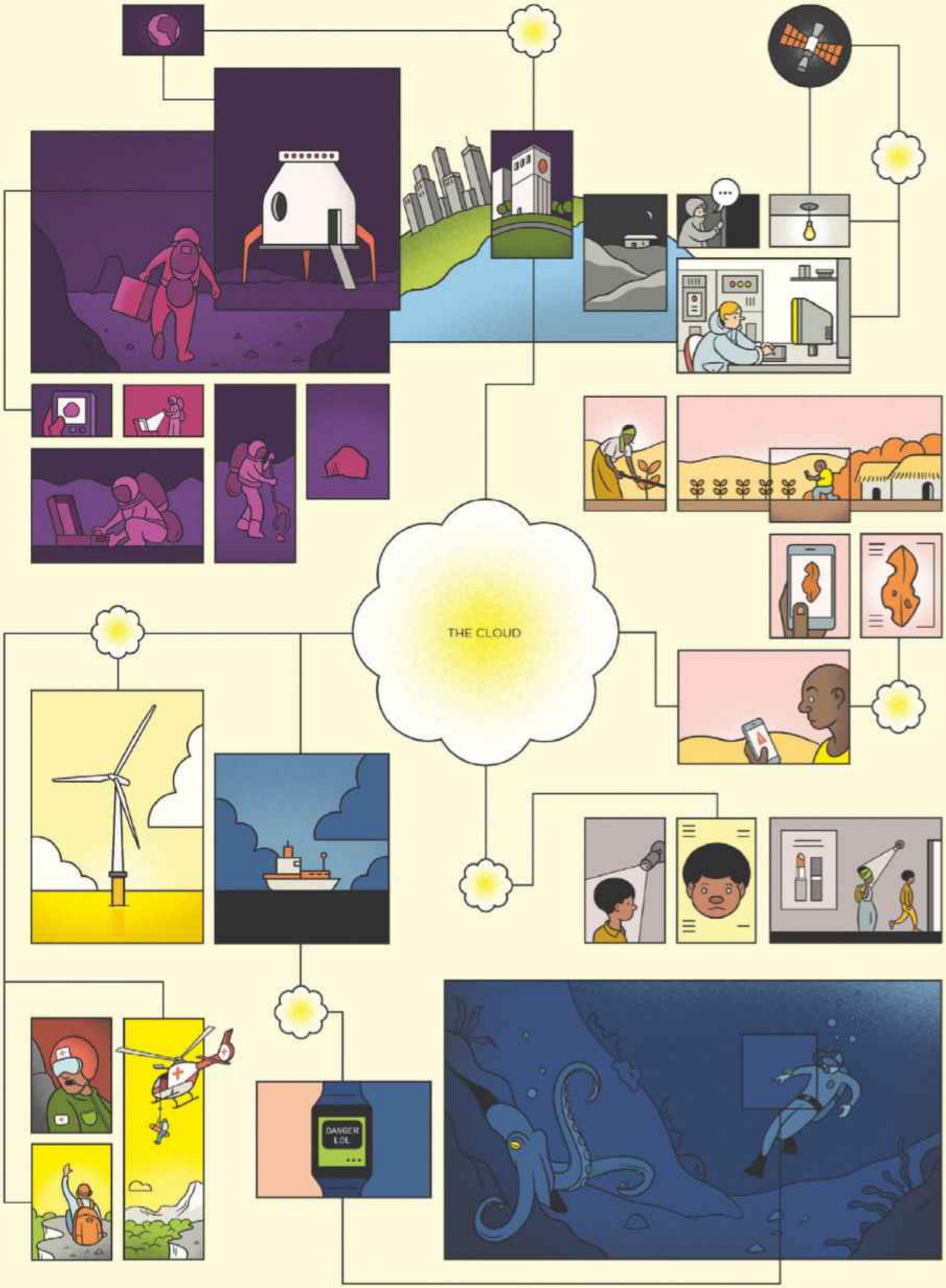

THE CLOUD
DANGER
LOL

Living on the edge

Low latency connections and decentralised servers will speed the spread of the IoT

By **Jody Medich**

2021 WILL SHOWCASE THE REAL POWER of distributed computing, with significant processing taking place not in centralised servers in the cloud, but on the "edge" of the network, where much of the data we rely on is generated. This will deliver big gains, not only in computing, but also in the lives of the increasing number of people who will be connected to the power of the internet as a result.

Edge computing will be crucial to the success of the internet of things (IoT). Between them, IoT devices – from smartphones and smartwatches to tiny computers embedded in machines and infrastructure – generate huge amounts of data. This is processed in the cloud, with relevant data then sent back to the device, instructing it how to react. But latency – the time it takes for data to travel between two points on the internet – makes this set-up unreliable for time-critical applications such as those used by medical devices, for example, which need to process and react to sensor data almost instantly. Relying on the cloud also limits the possibility of deploying IoT devices to locations with little or no internet connection. This might be outer space, deep under the sea, or places on the Earth's surface that are still poorly served by the internet.

In 2021 we will use edge computing to address these challenges by relocating the processing of data from a central server to geographically closer to where it was gathered. We will be able to do this thanks to specialist accelerator chipsets, developed by companies such as Nvidia and Intel, which are able to run relatively advanced machine-learning algorithms far from the powerful centralised servers of the traditional cloud and sometimes even on the device itself. This will reduce latency to almost zero. We are also developing software and hardware optimisation techniques such as model quantisation, which will speed up cloud-based processing, further reducing latency. Advances like these will help spread sophisticated IoT devices throughout the world.

Edge computing will also enable us to have more localised control over our data. A technique known as federated learning allows an algorithm to be trained across multiple servers or edge devices that hold local data samples, without that data having to be shared or exchanged. This means that sensitive data, such as medical or proprietary information, can be processed and kept secure on the device itself. An example of this already in use can be found on smartphone keyboards, which create a localised, personal library of common words and phrases for each individual on their device while sending only summarised changes of the AI model to the cloud for processing. This allows the AI to learn from use cases, but protects the privacy of users.

Jody Medich is CEO and co-founder of Superhuman-X

Because edge computing reduces dependency on connectivity, it will give more people access to AI solutions. This will have a big impact in areas of the world such as sub-Saharan Africa and parts of Asia and South America, where many people face serious connectivity issues. Edge computing is already, for example, being used to help subsistence farmers in sub-Saharan African countries. Apps such as Agrix Tech, developed by a Cameroon-based startup, use the camera and machine-learning algorithms in their smartphones to help farmers identify disease and pests on their crops.

The farmer gets this information immediately in the field. Then, when the phone is near an internet node, the app feeds anonymised data into the cloud to further train the centralised algorithm. Combined with a new generation of low-orbit satellites that will reduce latency in the cloud, edge-computing applications such as this are set to revolutionise online life for people in these regions.

In 2021 we will see more breakthroughs brought about by edge computing in medicine, transport, industry, agriculture and the home. Edge's ability to process data in an intelligent way as near as possible to its source will create an IoT that will deliver practical benefits to huge groups of people across the globe.

AI will rewrite maths proofs

We will see the first truly creative proof of a mathematical theorem written by an artificial intelligence

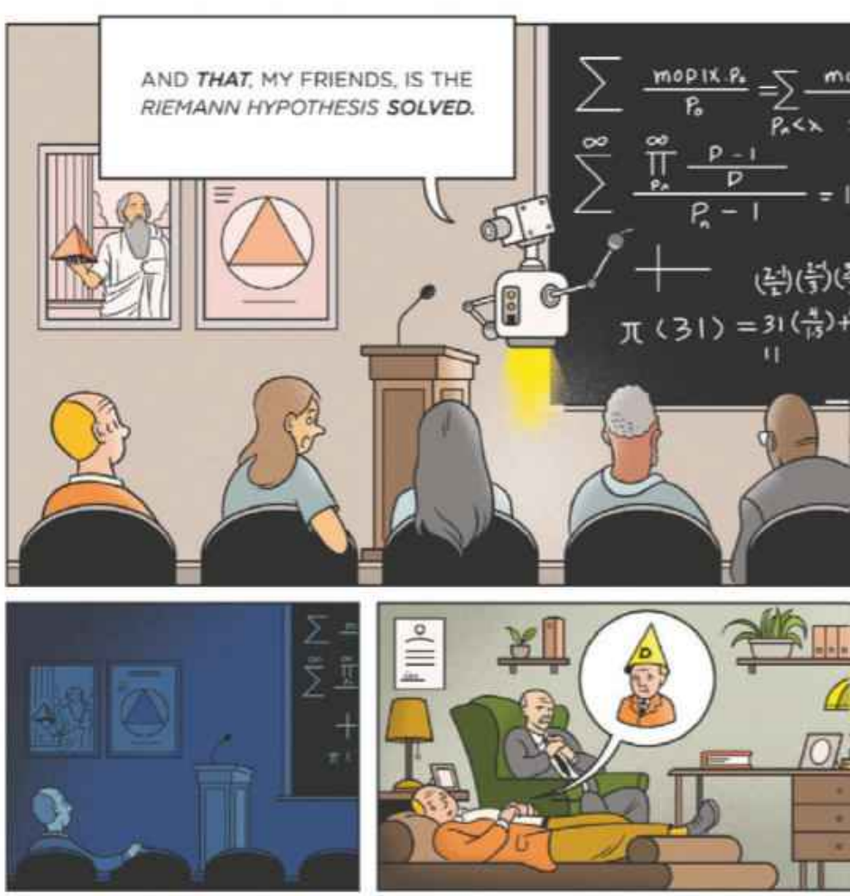
By **Marcus du Sautoy**

IT MIGHT COME AS A SURPRISE TO SOME people that this prediction hasn't already come to pass. Given that mathematics is a subject of logic and precision, it would seem to be perfect territory for a computer. However, in 2021, we will see the first truly creative proof of a mathematical theorem by an artificial intelligence (AI). As a mathematician, this fills me with excitement and anxiety in equal measure. Excitement for the new insights that AI might give the mathematical community; anxiety that we human mathematicians might soon become obsolete. But part of this belief is based on a misconception about what a mathematician does.

If I were simply sitting in my office in Oxford doing long division to a lot of decimal places, computers would almost certainly have put me out of a job by now. But mathematicians are not merely calculators. We are storytellers, weaving together logical tales that take our readers on a strange journey – one with twists and turns, surprises and drama. Our characters are numbers and geometries. Our proofs are our narratives. We are not trying to prove every true statement about these numbers and geometries. Rather, we are making choices about the stories we tell.

This is why I think that the challenge of AI coming up with a proof that will excite mathematicians is a much harder task than many might think. It will have to learn about our emotional world and to understand the proofs we care about. That is much more complex than simply bashing out equations that follow logically one from another.

It's not to say that there haven't already been proofs that have exploited the computer as an essential partner in exploring mathematically deeper than the human mind can manage. One of the first was the proof that four colours suffice



Marcus du Sautoy is the Simonyi professor for the public understanding of science and professor of mathematics at the University of Oxford and author of *The Creativity Code: How AI is Learning to Write, Paint and Think*

to cover any map, so no two countries with a common border are coloured the same. Once proved in 1976, a computer was used to check 1,834 maps that happened to be the building blocks of all maps. The computer was used like a telescope, allowing us to look further than the naked human eye could see.

More recently, techniques of machine learning have been used to gain an understanding from a database of successful proofs to generate more proofs. But although the proofs are new, they do not pass the test of exciting the mathematical mind. It's the same for powerful algorithms, which can generate convincing short-form text, but are a long way from writing a novel.

But in 2021 I think we will see – or at least be close to – an algorithm with the ability to write its first mathematical story. Storytelling through the written word is based on millions of years of human evolution, and it takes a human many years to reach the maturity to write a novel. But mathematics is a much younger evolutionary development. A person immersed in the mathematical world can reach maturity quite quickly, which is why one sees mathematical breakthroughs made by young minds.

This is why I think that it won't take long for an AI to understand the quality of the proofs we love and celebrate, before it too will be writing proofs. Perhaps, given its internal architecture, these may be mathematical theorems about networks – a subject that deserves its place on the shelves of the mathematical libraries we humans have been filling for centuries.

The journey ends for Explorer
Microsoft will shut down Internet Explorer in 2021. While businesses will still be able to use Internet Explorer in legacy mode, support for the browser across Microsoft 365 and its suite of apps will disappear. Internet Explorer was created in 1994, but struggled against challengers such as Chrome and Firefox.

In 2021, will we own and verify our identities

Proving you are who you are will get personal, thanks to data servers

By **Irene Ng** and **James Kingston**

IN A WORLD THAT IS INCREASINGLY DIGITAL, OUR online identities hold the key to accessing social, economic and democratic activities. According to a 2019 report by McKinsey, the potential economic value of digital identity by 2030 will be the equivalent of six per cent of GDP in emerging economies, and three per cent in developed economies. This will come from many sources, including increased use of financial services, better access to employment, escalated agricultural productivity, higher tax revenues and less fraud.

Yet, the World Bank estimates 1.8 billion people have no legal form of identity. Without this, individuals are more likely to be exploited, trafficked or confined to a life of servitude. And many of us who do have an online identity find that it is managed by companies such as Google and Facebook – organisations that, in many people's eyes, have a poor reputation when it comes to using individuals' data.

In 2021, individuals will gain the ability to own servers where their data is stored – and with it control their online identities.

Digital identification utilises three components: identification, authentication and authorisation/assertion. Identification involves binding a digital identity to a real-world person, such as happens when you open a bank

account. Authentication is about proving that someone is who they say they are – which is most commonly through the creation and use of a log-in password. Authorisation and assertion are the presentation of credentials that demonstrate that someone is able to access certain resources – such as a parent topping up a child's school-meal allowance.

All three digital-ID components require "source-of-truth" data for the individual's identity to be verified against, and digitally verifying these sources confers great economic power. Much of this data has been amassed by tech giants such as Google and Facebook, which have stepped into the role once held by the state.

These platforms are able to verify online identities through the vast amount of data they hold and through the fact that their servers can perform real-time, secure digital verification and authentication. (This is how Google and Facebook can offer smaller companies the means to verify and authenticate people logging into their systems quickly – the option to sign in "with" Facebook or Google.)

For those of us concerned about privacy and civil liberties, this is a problem. Each time Facebook or Google verifies a user's identity they become even more powerful through gaining more data about that individual and their transactions. By ceding identity verification to big tech, we are increasing its ability to surveil.

In 2021, people online will be able to verify their own identities. This will help the 1.8 billion of those who have no legal form of identity, and will reduce the power of the tech giants.

Companies such as Dataswift, with which we are involved, have developed personal data servers (PDAs) with computational abilities to create their own digital personas. Using this technology, individuals will be able to import their own sources of truth – such as banking and healthcare information and even data from Facebook – and use this for identity, authentication or authorisation with applications and websites directly.

PDAs can be created in seconds in the cloud with legal ownership transferred to individuals upon creation. They are able to authenticate themselves directly and give apps that use them access to the account without the app itself holding any identity information, such as an email. They also enable apps to request other data stored in the PDA. For example, individuals can show applications they are allergic to peanuts, because data from their healthcare provider acquired into the server can be used to authenticate and assert that fact without the need to give any identity information. By using PDAs, apps that rely on sensitive data will be able access this and stay "identity blind".

One effect of the Covid-19 pandemic will be the increased use of PDAs. In the US, ShareTrace, which manages Covid-19 symptom tracking, is already using the technology. And, in 2021, EMITTO, which helps travellers verify risks before they fly, will offer log-ins via PDA in its app. This will be a game changer. With 759 million travellers per annum, 2021 will see a huge rise in those obtaining a PDA, instead of logging in with Facebook and Google. And once PDAs have increased penetration in this way, they will be used by apps and online services across many other sectors.

In a society where digital technology is becoming yet more dominant, giving citizens the ability to own and verify their identity (or just their Covid risk score without identity) levels the playing field and holds the key to a more equitable future.

Facebook on your face

Facebook will launch its own brand of smart glasses in 2021, designed in conjunction with Paris-based Ray-Ban manufacturer EssilorLuxottica. The glasses will not feature a Google Glass-style integrated display, but the company says it is prototyping truly AR glasses as part of its current Project Aria AR research programme.

Irene Ng is professor of marketing and service systems, University of Warwick and CEO of Dataswift

James Kingston is VP Research Partnerships at HAT-LAB and director at Dataswift

AI will enhance remote learning

Overstretched teachers will gain a smart assistant in 2021

By **Kai-Fu Lee**

DISTANCE LEARNING HAS BEEN AROUND for years. But it still came as a rude shock to parents and children when the pandemic forced more than a billion students around the world to try to learn via a screen at home. Under-resourced teachers, unfamiliar technology and massively variable home-schooling conditions meant that, for some, the experience was fraught and ineffective. For many, it even left them questioning the very concept of distance learning. In 2021, however, we will see how technology, specifically artificial intelligence (AI), is the future of education, as it works alongside teachers to deliver successful online lessons.

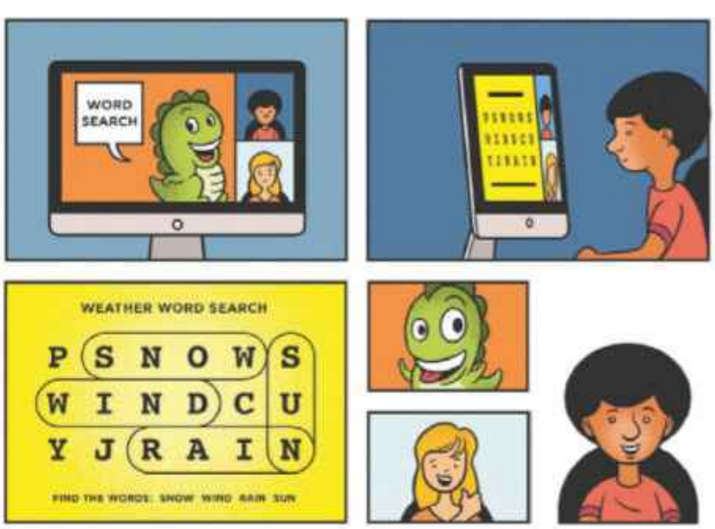
China leads the way in mass-scale e-learning solutions that combine human teachers and AI, with nine education technology unicorns of its own, including VIPKid, Zuoyebang and Yuanfudao. AI allows these companies to deliver a learning experience that caters to the specific needs of the child and helps them progress, rather than provide traditional lessons that leave some children behind and others bored.

Imagine Ling, a six-year-old first-grader learning to write complex Chinese characters. Her Chinese literacy platform, developed by Hexiaoxiang Network Technology, uses AI, computer vision and speech synthesis to deliver lessons. AI image-recognition software identifies each Chinese character Ling writes and generates assessments based on smart matching against a large training database. Speech synthesis and online videos give her real-time instructions and feedback. Human teachers on the platform can focus on personal coaching and support.

In the past few months in particular, AI has enhanced all four key areas of education: teaching, learning, practising and testing. Beijing-based online education company VIPKid, with more than 700,000 students, has launched an AI-embedded class, which includes animated fun characters who assist the human teacher. When the company ran a trial on 10,000 students comparing the AI-embedded classes against video-only classes, the results were striking. Course-completion rates went from 80 per cent to 90 per cent and correct answer rates from 50 per cent to 80 per cent. And all this online activity produces data that can be captured and used over time to provide even smarter AI inferencing.

AI used in this way can help reduce costs and enable more people of all ages to access education. And it will allow human teachers to delegate many routine tasks, such as planning, assessment, timetabling and even the imparting of facts, and instead focus on students' curiosity, critical thinking and creativity – the three C's that AI cannot replace.

Kai-Fu Lee is CEO of Sinovation Ventures



Machine learning goes physical

We will see real-world interfaces between humans and AI-driven machines

By **Alex Kendall**

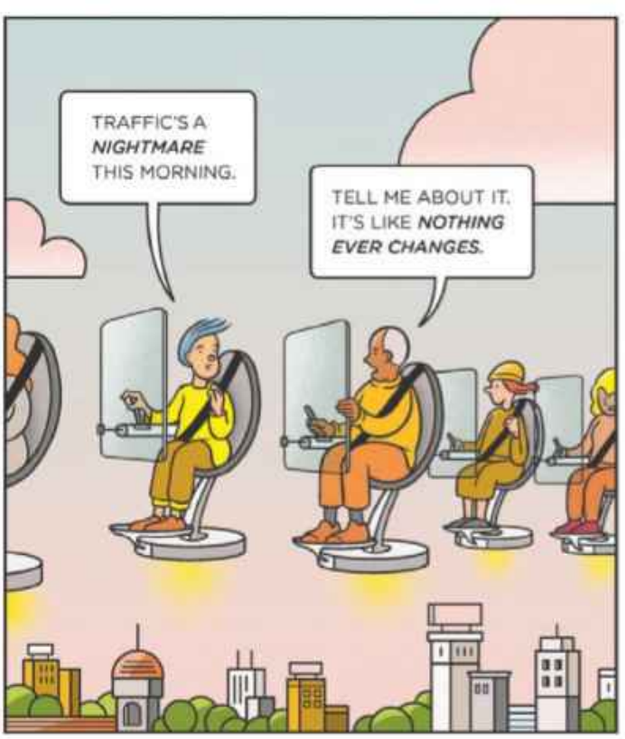
TODAY, THERE ARE MANY EXAMPLES OF artificial intelligence interacting with us to make our lives more efficient and effective. Machines recommend products for us to purchase through e-commerce websites, they rank news for us through social-media feeds, they introduce us to people on dating apps, price goods and services in real-time and so on. However, the common factor with all of these is that each machine is limited to influencing our lives through a software interface with a website or an app. In 2021, AI will go beyond this. We will see the emergence of the first physical interfaces between humans and AI-driven machines.

Today's autonomous machines operate in controlled and closed environments, such as factories and warehouses, physically separated from humanity. They are rigid, manually programmed machines with limited sensing and intelligence. However, advances in machine learning – such as self-supervised learning in computer vision, new techniques for probabilistic and generative modelling, and model-based reinforcement learning for control – have produced opportunities to create intelligent machines that can interact openly with society, and with limited human supervision.

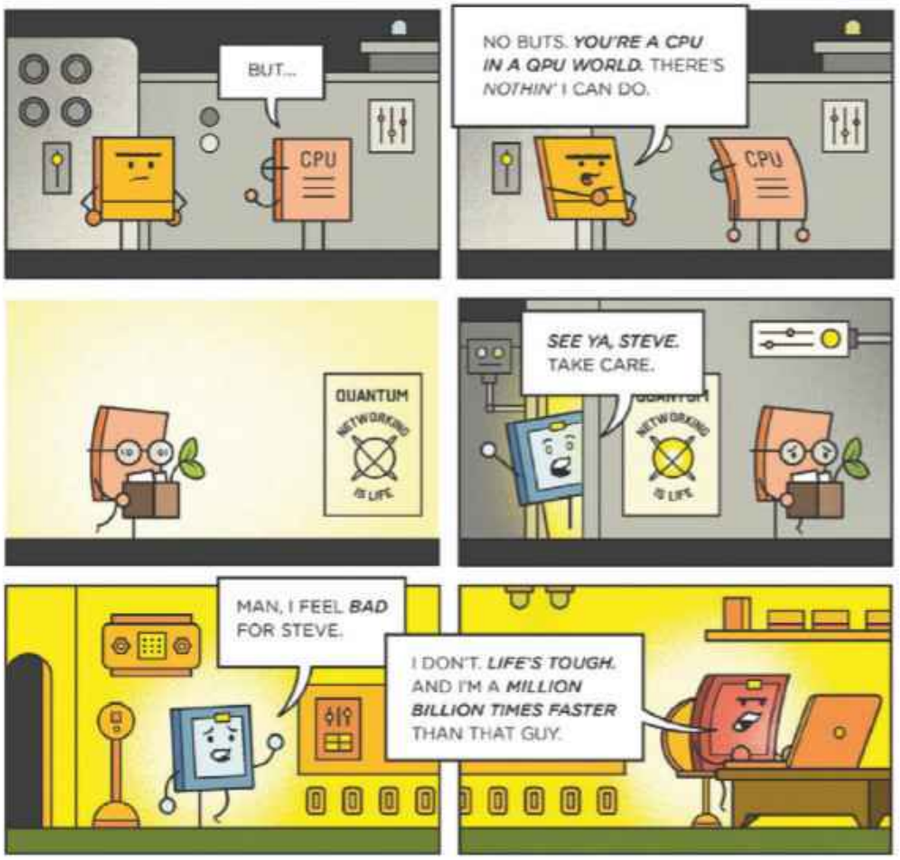
Machine learning has had a transformational impact on many AI problems, most recently in computer vision and natural-language processing. This has been catalysed with increasing access to petabyte-scale datasets and massive cloud computing, enabling a shift from hand-designed representations to end-to-end machine learning, which allows them to gain understanding beyond their original programming.

The reason why this change hasn't happened yet in robotics is because hardware is more challenging than software to scale safely, making training data more scarce in this domain. The recent breakthroughs in reinforcement learning, where machines are able to beat human world-champions at games such as *Go* and *DOTA*, relied on simulations, where infinite data could be generated to teach the machine. In 2021, however, we will take advantage of the petabytes of training data that have amassed, through many years of development, by mature robotic platforms such as self-driving cars.

One of the most interesting consequences of autonomous-driving technology is that society will be interacting with physical machines, without explicit consent, similar to how we interact with software machines today. Pedestrians will not consent to an autonomous robot driving down the street beside them; it will just be the norm because it is more reliable, safe and efficient. This will require extraordinary levels of trust from humanity in, and of performance of, self-driving technology, something that, thanks to the data we have now accrued in our work on autonomous vehicles, we are on track to achieve in 2021.



Alex Kendall is co-founder and CEO of Wayve


BUT...
CPU
NO BUTS. YOU'RE A CPU IN A QPU WORLD. THERE'S NOTHIN' I CAN DO.
CPU
QUANTUM
NETWORKING
SEE YA, STEVE. TAKE CARE.
NETWORKING
MAN, I FEEL BAD FOR STEVE.
I DON'T. LIFE'S TOUGH. AND I'M A MILLION BILLION TIMES FASTER THAN THAT GUY.

Quantum gets networked

Clustering will allow these powerful computers to scale massively

By **Peter Chapman**

WHATEVER THEIR UNDERLYING TECHNOLOGY, to achieve scale, quantum computers will need to go modular and be networked. In 2021 we will see the first demonstration of this.

Quantum technology is often linked to three different areas of networking. The first is to improve the security of the internet, by adding quantum encryption to its communications technology. Second is to build tomorrow's internet using next-generation quantum technology. And the third is to build more powerful quantum computers. It's in this third area where we will see a significant advance.

There are two proven ways to build a faster, more powerful computer. The first is to increase the performance of individual components, such as the speed of the processor. The second is to go modular and increase the number of components, adding, for example, multiple processors. IBM's Summit supercomputer uses this second approach. It is the size of two tennis courts and has 9,216 processors boosted by 27,648 graphics processing units.

The same two approaches apply to quantum computers. IonQ, IBM, Google and others are working on bigger and better quantum processing units (QPUs), the equivalent of CPUs in traditional computing. But it is also possible to get to scale by simply building more quantum computers and "networking" them, as we see with the cloud today. As your computational needs increase, the number of servers escalates to meet the demand. If you have a 100 qubit QPU and your application needs 2,000 qubits, you can simply "network" 20 QPUs together to create a cluster that acts as a single, more powerful quantum computer.

In "classical" computing, going modular often incurs some sort of penalty in terms of performance, or additional overhead cost in terms of both money and time. However, to allow multiple quantum computers to work together, we must entangle qubits across QPUs. Entanglement allows two qubits to remain connected so that actions performed on one affect the other, even when separated by great distances. After the qubits are entangled, they no longer care about locality, distance or source of the qubit, meaning there is no overhead to running them after the initial setup cost.

In 2021, we will see the first demonstration of modular quantum computers that are "networked" for the purpose of building a single, but much larger, example. This will happen in the real-world quantum industry, outside of theoretical experiments in academic labs, and will show us a clear path towards creating more powerful quantum computers.

Peter Chapman is CEO and president of quantum-computing startup IonQ

In 2021, AI assistants will teach themselves

Droves of data, self-learning algorithms and user feedback will enable artificial intelligence to get the gist in record time

By **Rohit Prasad**

WHEN CHLOE SAYS, "READING MODE", SWITCH TO 75% BRIGHTNESS.
I WILL.
SHE'S A VEGETARIAN AND I GO AND RECOMMEND BEEF STROGANOFF. I'M SUCH AN IDIOT.
DON'T BEAT YOURSELF UP OVER IT. YOU KNOW FOR NEXT TIME.
REMEMBER, "PLAY THE CLASSICS", MEANS 90s GRUNGE, NOT MOZART.
GUYS, SHH, SHE'S HOME!
GOT IT.

MAKING MACHINES ARTIFICIALLY intelligent is a time-consuming practice of collecting and manually labelling data for AIs to learn from. Today, researchers are enabling machines to learn new concepts continuously from far fewer data samples; in 2021, this will continue, as AI systems rely less on human labelling, and more on teaching themselves directly from interactions with users.

This will make a big difference to the "intelligence" of AI assistants. Today, it is second nature for us to complete transactional requests with AI assistants, either by issuing requests such as "Set the thermostat to 20°C", or "Navigate to Wembley Stadium". But, at the same time we are left yearning for more human-like conversational experiences, such as "Any ideas for this weekend?" or "Find me cameras under £400". As we enter the next decade of AI assistants, advances in deep-learning architectures and associated learning techniques will take us towards this more natural way of interacting.

The first of these advances will be what is called semi-supervised learning. This is where a small amount of labelled data is combined with large amounts of unlabelled data, and used to teach an AI system. For example, in an Alexa initiative for improving automatic speech recognition, a large "teacher" model was first trained on thousands of hours of labelled speech data. Then, the teacher was used to train a "student" model on millions of hours of unlabelled data. The student eventually outperformed the teacher in accuracy by more than ten per cent.

The second advance will be the emerging field of self-supervised learning, where the AI learns by predicting one part of the input from what it knows about another – without any human teacher. Bidirectional Encoder Representations from Transformers (BERT) for natural-language processing, created by Google, for example, uses large unlabelled corpora of data to "pre-train" a general language model, which can then be optimised for a specific task using a small amount of labelled data.

The third, and perhaps most significant step, will be AI self-learning from users' feedback signals. If an AI assistant does something wrong, users may repeat the request or paraphrase it to make their intent clearer. Using these feedback signals, AI assistants, including Alexa, are able to detect errors in their interpretation and correct them by reformulating user queries based on context.

In 2021, we will see more AI assistants teaching themselves with minimal human intervention. This will be a giant leap forward in our quest for AIs to learn concepts, acquire common sense and eventually reason like humans themselves.

Rohit Prasad is vice president and head scientist, Alexa Artificial Intelligence at Amazon

We're staying online

Lockdowns have proved we don't need an office to be productive

By **Jimmy Wales** and **Orit Kopel**

THE YEAR 2020 HAS TAUGHT US WHAT'S really important in life: health, family and a stable internet connection. Following the long weeks of social distancing and spending time at home, we were compelled to re-evaluate the merits of working from a shared office. Business meetings can now be conducted via video conferencing, collaboration is possible from the comfort of our own homes, and teams have proved how they can work efficiently without the need to co-ordinate everyone in a physical space.

Remote work through online collaboration isn't a new concept. Wikipedia, the ultimate achievement of this practice, will celebrate its 20th anniversary in 2021. Millions have contributed their own knowledge and collaborated to create what is widely seen as the best encyclopedia ever produced. Yet most of us have never met face-to-face, or felt the need to commute to the same office space to discuss the latest edits with Keynote slides, snacks and bad coffee. Wikipedia works so well because we can collaborate on our own time, from our own spaces, with a focus on the creation of great content.

For years, humanity has been engaged in the slow process of transferring some of its work into online collaboration. Through the shocking experience of this pandemic, we were forced to challenge our conventions on what requires physical presence, versus what can be done efficiently online. Do we really need to spend so much time and resources commuting? Must we share the same space where we're mostly working individually in front of our own screens? Aren't we sharing documents, communicating and collaborating with our colleagues through online platforms anyway, even while we're within the same physical space?

The coronavirus pandemic is the push we all needed to give remote work a big step forward. To reflect this, online work platforms will begin integrating extra social features in 2021, and harness the community aspects of working together, which a lot of us feel are missing.

With these systems in place, both teams and the company as a whole will benefit by focusing on the work itself, without the distractions and costs of office rental, commuting time and business travel.

This transition will allow us to collaborate more effectively while preserving interactions with our colleagues and maintaining the sense of communal belonging. We're creating the foundations for collaborative work in 2021 and beyond – and this isn't a temporary change. The old world isn't coming back.

Jimmy Wales is the co-founder of Wikipedia and Fandom

Orit Kopel is CEO of Glass Voices and co-founder of WikiTribune

Ubiquitous assistance Virtual digital assistants will overtake the world's population in 2021, according to research firm Ovum, with over 7.5bn devices due to be in use. Google's Assistant is predicted to take 23.3 per cent of total market share, followed by Samsung's Bixby software. Alexa will be on about 4 per cent.

Fast finance: how the pandemic has sped up digital transactions

The lockdown has accelerated the uptake of digitised payment – now it's time to expand what it can do

IN A MATTER OF WEEKS, THE CORONAVIRUS pandemic changed how we live and work. We hunkered down at home, giving over dining tables to school and office desks. Shopping for the essentials quickly became something of a mashup between *The Hunger Games* and *Supermarket Sweep* – with speed and contact avoidance being prized above all else.

In other instances, we took to socialising online, with 70 per cent of UK people making use of video-calling services between April to June. "I think you're on mute" became everybody's new catchphrase, we all adopted the "Zoom dress-code" of office attire from the waist up, and competed with colleagues for the most enviable bookshelf flex.

Meanwhile, our economy witnessed triple-digit growth in e-commerce. Any business that didn't previously have an online presence had to pivot fast, or risk irrelevance.

It is said that adversity necessitates invention – but this was a case of "go digital now, or you're done". When we did venture out, cash was spurned in favour of contactless payments. As lockdowns eased and people slowly returned to shops and restaurants, these new habits seemed to stick.

Fortunately, the payments industry was ready. "Nobody can prepare for an unprecedented pandemic, but we have been preparing for a shift to digital for a long time – putting in the work to make sure that acceptance of electronic payments is as widespread as possible," says Michael Miebach, Mastercard CEO from January 1, 2020.

"It is interesting to see how necessity drives adoption of new technologies and how things that were expected to take years were compressed within a matter of months,"

Miebach adds. For example, adoption of contactless payments accelerated amid the pandemic, with Mastercard recording a huge 40 per cent growth in contactless transactions in the first quarter of 2020 alone.

Will it last? Miebach believes it will. He points to the arrival of contactless card payments on the Underground in London: contactless transactions subsequently went up in coffee shops near Tube stations. "It's muscle memory," he explains.

Accelerated adoption of digital technologies is being observed elsewhere in financial services. Indeed, the Covid-19 crisis has become an inflection point for trends such as online banking, mobile payments and bill splitting apps, with growth seen in all.

For Mastercard, that demonstrates that the future of payments is actually beyond the physical card. Miebach recalls that, when Mastercard was expanding into emerging markets, they quickly realised that cards weren't going to work in a market that had undeveloped or limited payment acceptance infrastructure. "We were going to have to try something entirely different," he says.

QR payments, for example, in which customers scan a merchant's unique code which lets them pay using their smartphone, proved popular and effective in Asia and the Middle East and Africa. The use of QR codes amid the pandemic for contact tracing could see the idea gain traction in Europe and North America, too. "We're retrofitting innovation from emerging markets back into the developed world," Miebach says. "We have an innovation lab sitting out in Kenya that deals exclusively with innovative solutions around low-ticket payments, financial inclusion and so forth." The aim is to develop them for other markets, bringing inclusive payments to everyone.

The ultimate goal is to give businesses and their customers choice and control, regardless of how payments are made. Miebach points to messaging app payments, a system popular in China with AliPay and WeChat. "If a WeChat user visits Oxford Street and wants to pay with that particular technology, then we'll enable that," he says. "In the end, it's choice: here are the relevant technologies, pick the one that makes the most sense for you."

ILLUSTRATION: R FRESSON

The pandemic was digital 's time to shine – and for many, it was their first taste of contactless cash

'The fundamental role that we have is one of connectivity – any payment to any payee, any way that they want'

Elsewhere, 5G, the internet of things (IoT) and automation could change not only how we pay, but how we buy. "Those are going to open up opportunities for machine-to-machine payments, micro payments, social payments," Miebach says. For example, the IoT could allow machines to communicate and anticipate what people need, and ordering just when they need it.

5G combined with sensors could enable a touch-free retail experience, with customers charged as they exit the store, or let shoppers see which farm grew that orange in your basket of groceries, an idea that pairs 5G and blockchain. "5G will allow you to go beyond the payment transaction in terms of the experience. There's zero latency, you can do anything at the point of interaction," says Miebach.

Indeed, artificial intelligence and 5G could enable an entirely new world of data use. "All of the data that a 5G transaction can carry, somebody will want to understand it and make use of it," he says. "We can make sense of that in a principled way, ensuring that whoever owns the data decides what it's used for. We can be that trusted party in this fast-changing world with all these new players coming up."

'These technologies can push beyond financial inclusion to help people grow financial wellness and resilience'

Permissioned sharing of bank account and transaction data is central to open banking, which has many applications, but can notably be used to determine a person's eligibility for credit if they can't provide it by traditional means. "These technologies can push beyond financial inclusion to help people grow financial wellness and resilience," Miebach says. Juvo, for example, uses everyday mobile transactions to build a financial identity for those without a formal credit history.

Challenges remain, and chief among them is security. The pandemic saw a wave of fraudulent texts and emails, with around four in ten people saying they'd seen more such activity. "The simple notion of more digital and more data needs greater investment in cybersecurity to outpace hackers and fraudsters," Miebach says, emphasising the critical focus on securing financial transactions, using technologies such as AI and biometrics.

Mastercard's solutions include enhanced analytics to screen for attacks as they happen, as well as payment tokens to help secure online shopping. Other approaches include PhishAR's device-based two-factor authentication system to help reduce financial fraud.

For all the progress, the shift to digital will be considered a success when it includes everyone. "A vibrant economy and an inclusive economy are synonymous" Miebach says. Other digital innovations can help lower barriers to participation for people who are typically underserved by financial products and services, be that a voice-banking system or an AI that translates services into different languages.

Digital identity solutions can be a vital enabler of financial inclusion, providing secure access to a bank account for unbanked populations around the world. Governments need to help, adds Miebach, as without trustworthy identification for citizens, it's difficult to roll out digital banking. "When the private sector and the public sector co-operate, this will succeed and will work very well," he says.

For all of this, Mastercard is playing a key part in bringing the future of payments to life and joining together different payment systems, open banking platforms and more. "The fundamental role that we have is one of connectivity – any payment to any payee, any way that they want," Miebach says.

Those goals have been part of Mastercard's journey for years, but there's more to do. "Collaboration is the answer," says Miebach, so the shift sparked by the pandemic continues, enabling an inclusive, more secure and better financial system that works for everyone.
mastercard.com/startwithpeople

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Plant-based energy sources

Harnessing the abundant power of the Sun will enable a carbon-free society – and even send us to Mars

By **Daniel Nocera**

PHOTOSYNTHESIS IS THE SOURCE FOR much of the world around us. It produces wood for our buildings, fibres for our clothes, food to sustain life and much more, including medicine, dyes, rubber and, of course, fossil fuels. Indeed, our current society burns in one year what photosynthesis took one million years to make, leading to the enormous amounts of carbon now present in our atmosphere. In 2021 we will move towards harnessing this extraordinarily powerful process – artificially.

Photosynthesis is a two-step process, taking place first in light and then in dark. In daylight, a leaf uses the energy in photons from sunlight to separate water into its elemental components of oxygen and hydrogen. The oxygen is released into the atmosphere; the hydrogen is stored as a component of a molecule called nicotinamide adenine dinucleotide phosphate (NADPH). In the dark, the leaf absorbs CO_2 from the air and combines it with the solar-produced hydrogen to provide it with chemical energy in the form of sugars.

To replicate these two stages, my colleagues and I at Harvard University have created two devices, which we have called the Artificial Leaf and the Bionic Leaf. The Artificial Leaf is a silicon-based solar cell with different catalytic materials bonded on to each of its sides. Immersed in water, it uses the energy of sunlight to break down the water into oxygen and hydrogen. The Bionic Leaf extends this idea by incorporating a bacterium, *Ralstonia eutropha*, which absorbs carbon dioxide from air and combines it with the hydrogen produced by the Artificial Leaf to make liquid fuels.

In 2020, by replacing *Ralstonia eutropha* with another bacterium, *Xanthobacter autotrophicus*, we were able to develop a device that combines nitrogen from air and the hydrogen from the Artificial Leaf component to make fertiliser. The result is that, by using only sunlight, air and water, we have been able to manufacture renewable fuels and the building blocks for food production.

Artificial photosynthesis is ten times more efficient than natural photosynthesis. In 2021 we will begin to explore practical ways to scale up the technology. In the short term, this will lead to a new, decentralised infrastructure of energy, food and manufacturing that is carbon-free. Society is already using hydrogen, for example, to fuel vehicles.

In the longer term, we will see the manufacturing of plastics, pharmaceutical drugs and chemicals driven by the Sun. And, when we finally send humans to Mars, we will be able to use the process to break down the water in the astronauts' urine and combine it with the carbon dioxide they exhale to produce synthetically engineered drugs, vitamins, food, medicines and more.

The world is urgently seeking ways to produce what it needs without using fossil fuels. In 2021, we will move a step closer by harnessing a powerful natural process that was under our noses all along.

Daniel Nocera is Patterson Rockwood professor of energy in the department of chemistry and chemical biology, and director of the Nocera Lab at Harvard

The skies will get crowded

Satellite megaconstellations will need to evade astronomers' views

By **Lucie Green**

SATELLITES ARE CRUCIAL TO MODERN life – from weather forecasts to studying climate change and for communication. Now we are seeing the arrival of "megaconstellations" of satellites, in which multiple satellites function as a network to provide services such as global internet.

One company, SpaceX, has made the first significant steps in establishing a megaconstellation that will eventually comprise 12,000 satellites. In November 2019, it started launching its Starlink satellites in batches of 60, with the aim of providing a global broadband service. If priced correctly, this will especially benefit the 2.5 billion people who currently have no internet access. So far only about 800 satellites have been launched and it seems only the military has signed up to use them, but in 2021, SpaceX intends to have enough satellites and sufficient ground-based infrastructure to provide near-global coverage.

The impact of this will be that, no matter where someone is in the world, urban or rural, they will be able to get internet access. And it will be fast – up to a gigabit per second, with latencies from 25 to 35 milliseconds, according to the company – thanks to the fact that Starlink satellites will operate at a relatively low orbit of 550km.

Where SpaceX has led the way, others intend to follow. Blue Origin, founded by Jeff Bezos, plans its own megaconstellation of more than 3,000 satellites, called Kuiper. These will orbit between 590km and 630km above the Earth, and will also be used to provide broadband to those who are unable to access it terrestrially.

They also, however, have a less welcome impact. The satellites' solar panels reflect sunlight, making them appear as fast moving spots of light across the sky. Indeed, many of us have already seen the Starlink satellites in space shortly after their launch, crossing the sky as long "trains". This can be a problem for astronomers, who are already seeing their images "photobombed" by satellites, making them harder to analyse.

SpaceX has been engaging with this issue and taking steps to reduce the visible impact of its satellites by adding sunshades and altering their orientation so that they will be much harder to see with the naked eye. It is not yet clear what mitigating measures Blue Origin will take.

Megaconstellations will bring huge benefits to people back down on Earth, especially those who are currently unable to play a full part in the online world due to lack of connectivity, but in 2021 we will also have to ensure that they operate in ways that don't affect our view and our understanding of those other residents of the sky – the stars.

Lucie Green is professor of physics and a Royal Society university research fellow at the Mullard Space Science Laboratory, UCL

The equality equation

Science and technology will finally be forced to confront the lack of representation and opportunity in its ranks

By **Obum Ekeke**

IN 2020, THE COVID-19 PANDEMIC AND THE protests that followed the senseless death of George Floyd in Minneapolis made millions reflect on their own role in perpetuating social inequity and systemic racism. In 2021, we will act on that newly understood responsibility. We will work across sectors, disciplines and industries to deepen our understanding of systemic problems and collaborate to find meaningful solutions.

This will lead to real change in science and technology. In 2019, Black people made up only three per cent of the UK tech workforce – and only 2.6 per cent of UK technology company board members are from ethnic-minority backgrounds. Attempts to address this critical lack of representation have often been siloed and seen as only a "nice to have". In 2021 they will be a key focus of companies' strategies.

Throughout the sector, organisations will move from commitments and aspirations to outlining actionable strategies for increasing internal representation. There will be a stronger emphasis on stripping the bias out of candidate sourcing, hiring, promotions and performance reviews. In particular, companies will be more proactive about reaching outside of their traditional networks to identify outstanding talent from less traditional backgrounds.

In academia and other fields that require postgraduate-level qualifications, such as AI, concrete steps will be taken to increase the numbers of Black people choosing, and given the opportunity, to study science and technology.

This is crucial, because disparities set in long before someone submits a job application or even enters the classroom. In the UK, only 2.2 per cent of school teachers, 0.65 per cent of university professors, and 15 of the 445 people who graduated with postgraduate research degrees in computer science in 2018/19 are Black. This challenge is compounded by narrow curriculums, insufficient role models in leadership positions, a lack of options for promising students and minimal funding for postgraduate study and network-based PhD admissions processes.

There will be a focus on supporting Black students' attainment in maths and science at GCSE and A Level, and admissions processes at universities will be made fairer. In universities, there will be more support for Black students to progress from Bachelors to Masters to PhD, work-experience schemes supporting Black graduates will be expanded and support for early-career Black researchers will increase.

Many organisations are doing great work: OpenAI offers scholarships to people from under-represented groups who want to study deep learning, and DeepMind, which I work for, has collaborated with more than 20 universities around the world to expand its own scholarship programme – which is focused on increasing representation at the postgraduate level through mentorship and financial support.

Beyond education, charities and other organisations working to address racial injustice in the sector and create opportunities for Black scholars – such as Data Science Africa, Black in AI and Colour in Tech – will see increasing support and engagement.

In 2021, the science and technology sectors will stop looking for quick fixes to address under-representation. Organisations will collaborate across sectors to proactively remove barriers to access and articulate a vision of life for Black people in science and technology at every level. In 2021, we will start to see meaningful change.

Obum Ekeke is global lead, university relations & education partnerships at DeepMind

Fragrance will become the new interface

Transformative olfactory content will change how we learn, shop and communicate

By **Natalia Kucirkova**

Natalia Kucirkova is professor of Reading and Children's Development at the Open University, UK, and the University of Stavanger, Norway

SCENTS AND SMELLS PROVIDE us with unique clues about the environment but, unlike animals or plants, humans massively under-use this wealth of olfactory information. This will change in 2021, and smell will be treated as data to enhance products in real time and in response to users' engagement.

Smell-based communication has been mooted for some time, but in 2021 we will see sophisticated ways of encoding, recording and reporting olfactory signals. Processing of olfactory data will be added to search-engine/voice-search queries and integrated with multi-media information for sales, marketing, public messaging and educational purposes. Companies such as Olorama Technology, based in Valencia, and Aromyx in Mountain View, California, are already developing smell simulators, voice-activated scents and bespoke odours tailored to individual projects and customers' needs.

The use of smell for detecting unique and specific aromas is a learnable skill and training of the nasal passages will be part of progressive education curricula. New partnerships in the public-education sector will ensure the development of training and apprentice schemes geared towards changing teachers' perceptions and talents regarding the importance of smell in learning. Educational resources (such as scratch 'n' sniff cards for vocabulary teaching or scented books for fuller story immersion) will be used to facilitate memory retrieval and reading comprehension in primary and secondary students. With my colleagues, we are conducting trials using olfactory books that connect specific smells and children's learning of new words.

The brain structures common to odour and emotion processing – the amygdala, hippocampus and insula – were identified a decade ago, but the connection between mood disorders and olfaction has been underrated in medical practice. In 2021, medical practitioners will use intravenous olfactory tests to detect and prevent olfactory dysfunction. Currently used in Japan, such tests are more affordable and do not require specialised labs (unlike standardised olfactometers). They involve an intravenous injection of Alinamin, which produces a garlic-like odour sensation and is used as part of subjective olfactory tests. Increased use of antiseptics and sanitation products, and an altered sense of smell in Covid-19 patients, will decrease natural olfactory sensitivity among the general population, raising the risk for behaviour and mood disorders. Pharmaceutical companies will capitalise on the known olfaction/emotion interactions, such as the effects of citrus-based fragrances to treat depression and anxiety.

Olfactory data will be embedded into new interfaces, which will be leveraged for monitoring and maintaining routine tasks. For example, using dynamic GPS tracking

and environmental-odour detection, driver behaviour will be checked for adherence to scheduled meal breaks or length of engine use. The Cybernetic AI Self-Driving Car Institute proposed an "e-nose" for AI self-driving cars in 2018. In art, perfume-based artworks, such as those modelled by Martynka Wawrzyniak's olfactory self-portrait, will use aromatic elements and biological oils extracted from the human body to create bespoke self-expressions. Online and in-store shopping will be enhanced with VR to deliver immersive, multi-sensory experiences individualised to clients' needs and budgets. For example, natural extracts of wood or pines (that do not mix and are released in regular intervals) add to a realistic experience of being in a forest. Retailers will invest in improving customers' in-store experiences with scented areas. For example, at one of its events, Lancôme featured videos synchronised with eight different scents. In digital commerce, brands that redesign their websites to support olfactory exploration will increase their sales.

Given that many natural scents are disappearing, there will be significant availability problems around essential oils, such as jasmine or sandalwood, that cannot be synthetically produced. New legal and regulatory frameworks might need to be established to protect the preservation of unique natural smells such as rose or lavender. The fragrance industry will adapt to the environmental degradation processes by producing perfumes based on completely synthetic smells. However, 2021 will be a rough year for the natural perfume industry, with many artisan producers facing barriers to entry thanks to the over-regulation and homogenisation of the market.

While 2020 was about automating and optimising olfactory technology, 2021 will be the year of transformative deployment of olfactory content. Olfactory interfaces will become the new norm in all areas of retail and communication, with a possible shift for replacing standard touchscreens in the future.

The nuclear cleanup begins Japan will begin removing melted fuel from the Fukushima nuclear-power station in 2021, a decade after the explosion in 2011. The job will involve the safe removal of more than 800 tonnes of fuel across the three reactors. Japan's Ministry of Economy, Trade and Industry says full decommissioning may take from 40 to 60 years.

Artificial body parts will break through

Scientists will crack the cellular code to enable on-demand transplants

By **Paola Bonfanti**

ARTIFICIAL ORGANS – GROWN IN THE lab and transplanted into someone's body – have been on the horizon for some years now. They present many challenges but, if we can overcome them, they will open up the possibility for patients who need a new organ no longer having to wait for a human donor. They will also save health services money, eliminating the high costs that accrue during years of treatment, especially for some chronic conditions.

In 2021, we will see significant breakthroughs around how artificial organs function, while the technology used to produce them will take them one step closer to use in the clinic.

To date, the greatest success we have had in this field has been the production of lab-grown epidermis, the outermost layer of skin, to replace that which has been destroyed by burns. This is achieved by growing the stem cells of a patient's own epidermis (from an area spared by the burn) in culture and then transferring their progeny on to a thin layer of fibrin, which is then transferred on to the affected surface. The new epidermis attaches and functions

for decades, although it is unable to produce hair or sebaceous glands. This technique has saved the lives of thousands of burns patients and is in use in hospitals across the world.

But we can go further than that. In 2017, Michele De Luca and Graziella Pellegrini at the University of Modena in Italy, corrected the DNA in stem cells taken from a child with epidermolysis bullosa, a chronic ailment that makes the skin prone to painful tears. Through a combination of stem-cell and gene therapy, they were able to graft new in-vitro-grown epidermis on to his body, curing him of the devastating genetic disease. Five years after their intervention, the child's skin is still normal and authorisation has been requested to use the technique to treat other forms of this disease.

In 2020, Karl Koehler and his team at the Boston Children's Hospital were able to use human stem cells to grow the whole thickness of the skin, rather than simply the epidermis. This will allow other medical teams to treat those diseases or injuries that also affect the dermis, the inner layer of the skin. Some time will still be needed, however, before seeing this entering experimentation, as clinical-grade scale-up will be needed first.

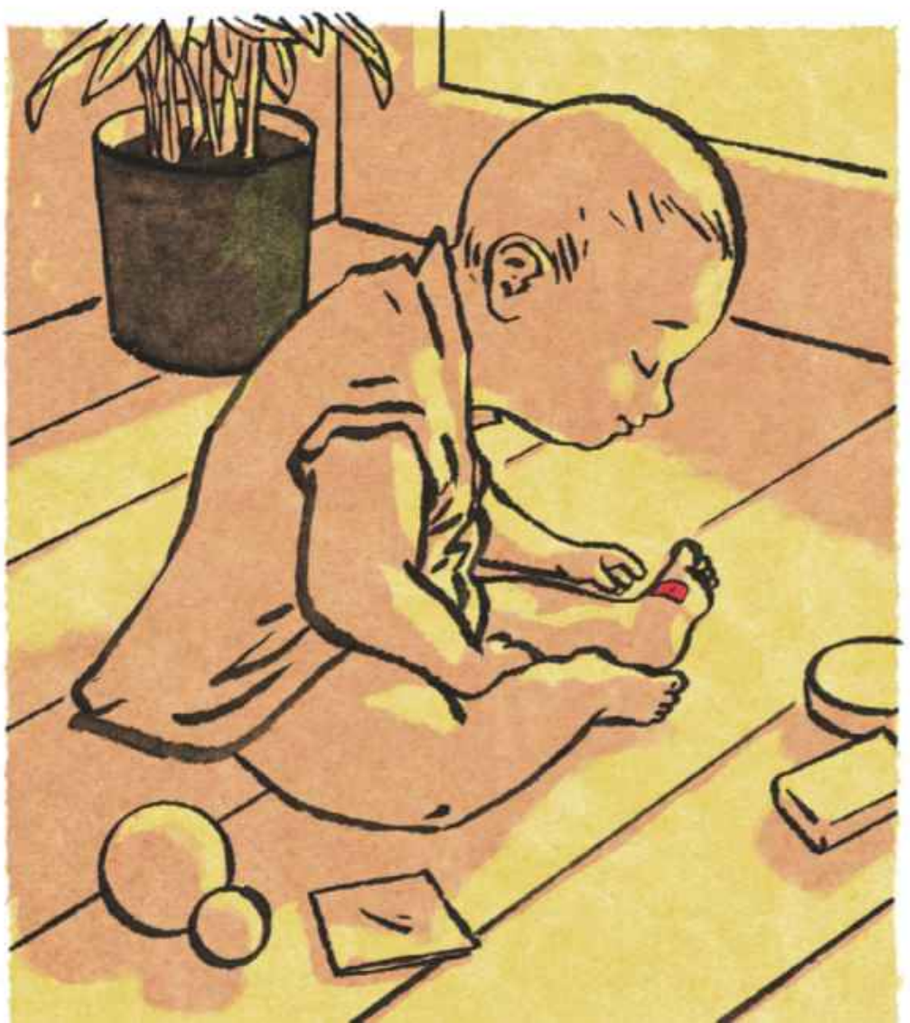
In 2021, we'll see other organs grown. In my lab at the Francis Crick Institute, we're creating an artificial thymus, entirely reconstructed from cultivated human stem cells.

The thymus is crucial for the development of cells called T lymphocytes, which fight off and destroy infectious agents or cancerous cells. Some children are born without a thymus, making them intensely vulnerable to infections. A new organ would offer a route to a normal life. The thymus is also distinct among all organs as it helps lymphocytes recognise and therefore not harm our own healthy cells. Potentially any transplanted patient could benefit from an artificial thymus grown from the donor's stem cells. This would reset the patient's immune system so it recognises the donor organ as if it was their own, eliminating the need for life-long immune-suppression drugs.

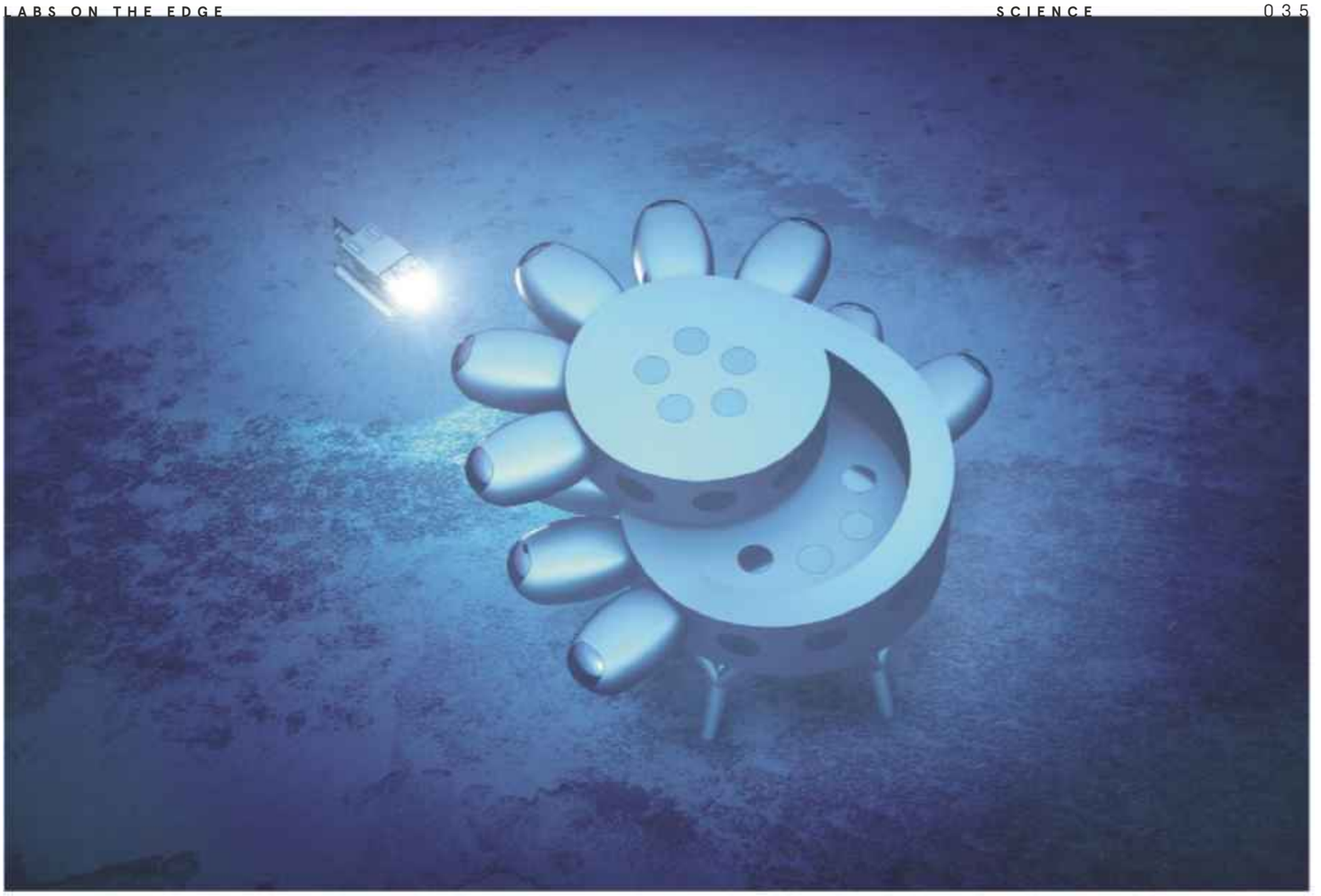
Growing an organ isn't easy – you need to ensure that stem cells turn into the correct cell type for a specific organ

Growing an organ isn't easy, though. Technicians need to ensure that stem cells turn into the correct type of specialised cell needed for a specific organ, and that these are in the right proportions and position. In 2021, we'll see more of the technology needed to grow complex organs. Researchers in many laboratories are working on improving bioreactors – machines that provide the precise conditions, such as temperature, humidity, nutrients, oxygen and movement, needed to create organs and mimic their function in the body.

In 2021, researchers will also expand our knowledge of stem cells. In my lab, for example, we are working on an artificial oesophagus to better understand how these cells behave in order to develop the organ's complex structure that ensures its physiological function. Next-generation DNA sequencing also allows us to decipher rapidly and with extreme precision which genes are expressed in a given tissue and to what extent. This means we can uncover exactly how artificial body parts compare to natural ones, which is a crucial issue, especially as we want these new organs to last a lifetime.



Paola Bonfanti is group leader of the Epithelial Stem Cell Biology & Regenerative Medicine Laboratory at the Francis Crick Institute



Extreme science

By **Sanjana Varghese**

Around the world, scientists and researchers are tackling some of the planet's biggest problems – such as climate change, environmental degradation and rising sea levels – at their source. In order to achieve this, a series of research facilities and laboratories are being built in extreme environments, such as in the Antarctic, deep underwater and nestled alongside remote ecosystems. The work done there will help us redefine our relationship with the natural world – and even provide insight as to how to begin new lives on other planets – while also providing forward-thinking architects with opportunities to reimagine what a scientific laboratory can look like.

1. Proteus, Curaçao, Dutch Caribbean
Work begins in 2021 on Proteus, which when complete, will be the world's most advanced underwater scientific research station. A collaboration between Swiss designer Yves Behar and the US-based Fabien Cousteau Ocean Learning Center, the complex will span over 371 square metres and be powered by ocean, solar and wind energy. The structure will include pod apartments for visitors and an underwater greenhouse kept temperate by thermal energy. *fabiencousteauolc.org*

2. Henry Arctowski Antarctic Research Station, King George Island, Antarctica
Warsaw-based Kurylowicz & Associates will refurbish the 40-year-old research station in 2021. The building will be raised three metres above ground, which will allow water, wind and snow to move underneath the structure, and it will have a new greenhouse for the 29 residents to grow their food. Power will come from nearby wind turbines. *arctowski.aq*

ARTWORK: ENNEAD ARCHITECTS

3. Cape Horn Sub Antarctic Research Centre, Navarino Island, Chile
Designed by Ennead in New York and Chilean architects Cristian Ostertag Chavez and Grupo Cuatro, this lab is scheduled for completion in 2021 and will be used to study local ecosystems. Its three pavilions will be clad in pre-weathered steel and the green roofs will collect rainwater. *ennead.com*

4. Experimental Bioregenerative Station (EBIOS), Mojave Desert, US
Interstellar Lab's EBIOS will begin construction in California in 2021. A carbon-neutral village made of glass-clad domes, it will generate water, food and energy for 100 people as part of a trial for living on other planets. Rooms will be available to rent for up to $6,000 per week. *interstellarlab.earth*

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CRISPR will move from lab to clinic

We will discover even more uses for the innovative gene-editing technology

By **Jennifer Doudna**

SINCE MY COLLEAGUES AND I FIRST DESCRIBED CRISPR as a genome-engineering tool in 2012, the technique has transformed fundamental research. More than 15,000 papers containing the term have been published, hundreds of different organisms have been edited and this approach to gene editing has been widely adopted by scientists working on real-world solutions that can change millions of lives.

In 2021, researchers will use CRISPR to enhance our medical response to the Covid-19 pandemic. Teams will continue to collaborate and bring to market vital CRISPR-based diagnostic tools that are accurate, rapid and painless. One currently being developed and scaled by Mammoth Biosciences, a company I co-founded, along with partners at the University of California, San Francisco and the pharmaceutical company GSK, can detect and indicate the presence of SARS-CoV-2 RNA in a similar fashion to a pregnancy test.

While these tools will enable our society to reopen (and stay open) by improving detection of the virus, CRISPR will also have an important effect on the way we treat other diseases. In 2021, we will see increased use of CRISPR-Cas enzymes to underpin a new generation of cost-effective, individualised therapies. With CRISPR enzymes, we can cut DNA at precise locations, using specifically designed proteins, and insert or delete pieces of DNA to correct mutations. As we deepen our understanding of the human genome and genetic disorders, patients with previously intractable diseases, such as sickle-cell disease and cancer, will benefit more widely from CRISPR-based therapies that are rapidly moving from the lab to the clinic. In 2019, sickle-cell patient Victoria Gray, for example, became one of the first patients in the world to receive CRISPR therapy for her genetic disease. She has already seen significant improvements to her health, including reduced pain and less frequent need for blood transfusions.

CRISPR will also allow us to act more boldly in the face of other important, interconnected issues such as food security, environmental sustainability and social inequality. The technology will help us grow more nutritious and robust crops, establish "gene drives" to control the spread of other infectious diseases such as Zika, and develop cleaner energy sources such as algae-based biofuels.

The positive impact of CRISPR will not absolve us of ongoing questions about its safety, fair access and ethics. The co-ordinated effort led by the WHO and the US National Academies of Sciences, Engineering, and Medicine to ensure that CRISPR does no harm ramped up after 2018's "CRISPR babies" controversy. Come 2021, talk of moratoriums, which cannot be enforced by scientists or legislators, will be replaced by robust discussion about how to establish appropriate regulations that will not stifle the technology, but allow it to reach its potential to help those with the greatest need. Furthermore, our global efforts will redouble to ensure the technology continues to power scientific research, create new jobs and ultimately redefine how humankind might prosper. In a world forever changed by Covid-19, we will find ways to responsibly apply CRISPR in 2021 and beyond.

Jennifer Doudna is a UC Berkeley biochemist and co-inventor of CRISPR

Stepping up PreP trials
The WHO will announce the results of its HPTN 084 trials into the efficacy of cabotegravir, an antiretroviral for pre-exposure prophylaxis (PreP) against HIV in women. A trial in men was halted in 2020 after proving highly effective. Rather than a daily pill, an injection would be required every eight weeks.

Treatment cross-pollination will elevate healthcare

In 2021, patients will feel the benefit as ideas from the operating theatre transfer to intensive-care wards

By **Emery Brown**

IN 2021, WE WILL START TO USE IDEAS from the operating room in the intensive-care unit (ICU). The Covid-19 pandemic has compelled us to rethink our understanding both of the human body and of systemic medicine. We have seen that pathological inflammations in patients with the virus can appear anywhere, and patients can present disorders in any organ system, from simple fevers to major strokes. This has led to novel approaches concerning the treatments being tried in hospitals and traditional divisions between departments breaking down.

One example is how we monitor patients who are sedated. Sedation is a major part of treating an ICU patient who needs a ventilator, just as it is of treating one in an operating theatre. In the past we have taken different approaches to monitoring how sedated a patient is. In an operating theatre, anaesthesiologists generally use electroencephalogram (EEG) recordings to monitor a patient's level of unconsciousness. In ICUs, however, clinicians typically have used clinical assessments instead.

This has changed under Covid-19. During the pandemic, we have started to see more requests for help with EEG machines in the ICU to assess patients' levels of arousal. This is because the virus affects everything, including the brain, and an understanding of how a patient's brain is functioning is crucial to providing the right level of sedation.

One key reason that this kind of cross-pollination occurred, in the hospital I work in at least, is that many of the staff who were redeployed during the pandemic when we were trying to keep everything running early in the year, were anesthesiologists, anaesthesia residents and anaesthesia nurses. In 2021, we will see more exchange of ideas like this between departments and other specialties. The pandemic has taught us the benefits of these new partnerships, and they will continue in the months and years to come.

Of course, these conversations have been ongoing among our communities from even before the pandemic struck – but Covid-19 has accelerated the willingness of seasoned experts to try new approaches. When it comes to using EEG monitors in ICU, there remain issues around cost and training. But these kinds of developments could herald a new age in our understanding of the systems that comprise our bodies and how we devise effective therapies, particularly when we find ourselves working in resource-limited situations that we have never been prepared for.

Emery Brown is the Warren M Zapol prof. of anesthesia at Harvard Medical School and a practising anesthesiologist at Massachusetts General Hospital

Vaccines will be personalised

Greater understanding of immunity will boost efficacy

By **Daniel M Davis**

WITH ANY LUCK, AT LEAST ONE OF THE VACCINES being developed will protect us from Covid-19. However, when candidate vaccines are tested in large groups of people, not everyone will respond in the same way. We may find that one type works better in young adults and another works for elderly people. This will open up a new frontier of science concerning vaccines tailored to benefit different groups of people. In 2021 we will understand that one-size-fits-all is not optimal for anyone.

There are still many gaps in our understanding of how vaccination works. We know which immune cells have to be activated – memory B cells and T cells – and we have ways of testing whether they have been. But we don't understand what's needed to ensure that immunity lasts for many years, rather than for a few weeks or months. We also know that elderly people tend not to respond to vaccines as well as younger people, but we are not sure why. It's not that our immune system simply becomes unresponsive as we age – elderly people are also more likely to suffer from auto-immune diseases, caused by unwanted immune responses. Rather, our immune system somehow goes awry in old age. Understanding why this occurs will open up the possibilities of vaccines that are especially effective in older people, specifically targeting a part of the human immune system known to work well in old age. There is already a precedent for this. A molecule called flagellin, found in bacteria, has been identified as one of the few germ molecules easily detected by the immune system in senior citizens. Including this molecule in a flu vaccine has been shown to help stimulate an appropriate immune response in elderly people.

And that will just be the beginning. Every person's immune system is configured slightly differently. In part, this is down to our genes – those which vary the most from one person to the other are not to do with anything physically obvious, such as our eye, skin or hair colour; they are immune-system genes. This is one reason why people fare differently when exposed to the same infection. And the infections each of us has been exposed to, our gender, where we were brought up, our diet and levels of exercise also all have an affect.

In 2021, we will increase our knowledge of the diversity of human immune responses. One large collaboration led by the US National Institute of Allergy and Infectious Diseases has already begun collecting huge amounts of information about different people's immune responses during Covid-19 infection. We will also see the results from several phase-3 clinical trials of Covid-19 vaccine candidates and, in most cases, this will include careful profiling of people's immune responses. This will seed new insights on immunity and generate the data needed for vaccines to be used in a more personalised way.

We will also understand more deeply other issues that affect our response to vaccines. It may emerge, for example, that giving someone a vaccine at a certain time of day will enhance its efficacy, as we know that our immune reactivity fluctuates by day and night.

Not only will these details help us tackle the current coronavirus pandemic, they will change how we use vaccines in general. In 2021, we will see an important step being taken towards truly personalised vaccines that work.

Daniel M Davis is an immunologist and author of *The Beautiful Cure*

Telemedicine comes online

In 2021, digital, data-driven systems will give consumers power over their healthcare

By **Sonali De Rycker**

IN 2021, PEOPLE WILL GAIN ACCESS TO THEIR health data and use it to make decisions about their medical care. And those funding healthcare – public bodies or private organisations – will redesign systems to meet these expectations.

Research published in July 2020 by GSK, the pharmaceutical conglomerate, found that 84 per cent of people in Spain, 77 per cent in the UK, 75 per cent in Italy and 63 per cent in Germany consider it important to take their health into their own hands to relieve pressure on healthcare systems. Consumers have also become accustomed to managing many aspects of their lives remotely via technology; they wonder why the same is not possible when it comes to their health.

Healthcare systems will evolve to accommodate the demands of individuals who want to engage not as patients, but as consumers, owning their healthcare journey through education, prevention, diagnosis and choice of services. The development of next-generation digital healthcare will become increasingly pivotal to meeting society's new needs.

One change we are already seeing is the rapid expansion of telemedicine. In April, the UK's Royal College of GPs reported that doctors were seeing just seven per cent of their patients face-to-face, compared with 80 per cent in 2019. Rather than calling a surgery for an appointment, many patients now complete an online e-consultation form – where they enter details of their symptoms – before being phoned by a doctor. This emerged as a Covid-19-related measure, but the UK government has said it would like to see the majority of GP consultations done this way in 2021. The evidence suggests that consumers should be broadly in favour of this approach. A 2018 survey for the Nuffield Trust, the health think-tank, found that 63 per cent of UK adults would be willing to have a video consultation with their GP for a minor ailment, and 55 per cent for advice on an ongoing condition or problem.

This shift towards digital delivery is being matched by a greater sense of urgency among healthcare-procurement systems. In March 2020, the UK's National Health Service selected digital-health providers through a procurement process completed in a record-setting 48 hours. Doctors, who have a critical role in this evolution, are also starting to acknowledge the productivity benefits of telehealth and remote care. A survey of primary-care providers in the US in 2020 found that 40 per cent believe digital health solutions provide "definite advantage" in patient care.

In 2021, we can expect to see a conflation of these trends, with at least some public-payer systems offering consumers access to their own data, and changing reimbursement to let people make more decisions around prevention and self-help. This might involve, for example, allocating some budget towards letting patients order their own screening tests for certain conditions, if a combination of their own data, family history and symptoms mean they feel at risk.

As the legacy of the pandemic starts to crystallise, in 2021 will see digital technologies shape healthcare systems that are based around the needs of the most important stakeholder – not the payer or the provider, but the consumer.

Sonali De Rycker is a partner at Accel, a venture-capital firm specialising in seed-stage funding

AI will detect disease at its earliest stages

We will combine genomics, MRI scans and artificial intelligence in a multimodal approach to healthcare

By **Craig Venter**

IN MANY COUNTRIES, COVID-19 HAS spread because of a popular scepticism about science, a political manipulation of data and an abundance of inaccurate information, spread in large part on social media but fuelled at some of the highest levels of governments. In 2021, we will understand that only by developing new, science-based approaches to disease detection will we avoid similar future catastrophes.

My own country, the United States, has already provided a live demonstration of this fact. States that enforced practices such as social isolation/distancing, hand washing and use of sanitisers and face masks have had the lowest per capita rates of Covid-19 infection, averaging around 100 to 200 cases per 100,000 people. Compare that figure to the 2,300 per 100,000 people in states that did not enforce these measures.

Reconnecting science with healthcare will have impressive results. One weakness of the world's response to the pandemic has been its unwillingness to use science to predict vulnerabilities in individuals before they become ill. Not only have many countries been reluctant to perform widespread testing on people who show no Covid-19 symptoms, but they have also been caught seemingly by surprise when pre-existing conditions have exacerbated the disease. In 2021, we will see the application of a multimodal testing approach to detect propensities to diseases in people at very early stages.

We are used to the idea that sequencing an individual's genome can give a reasonable indication of the likelihood of developing a particular disease. In 2021, we will combine genomics with MRI imaging and machine learning to provide a more sophisticated snapshot of an individual's health. In research published in 2020, my colleagues at Human Longevity and the J Craig Venter Institute, of both of which I am the founder, analysed data collected on thousands of individuals. By integrating whole-genome sequencing with advanced imaging and the analysis of blood metabolites, they were able to identify adults at risk for key conditions including cancer, heart disease, diabetes, chronic liver disease and more.

The study demonstrated the importance of multimodal testing, rather than relying solely on the sequencing of an individual's genotype. A lack of phenotype and genotype associations were observed in 5.8 per cent of individuals with pathogenic genetic variants, further suggesting that the identification of pathogenic genetic variants by sequencing alone is not sufficient for a definitive diagnosis.

We intend to scale up this study in 2021 to test multimodal, preventative-medicine procedures on a larger cohort. The pandemic has temporarily derailed this effort but, with strong, knowledge-based leadership and a renewed trust in science, my hope is that 2021 will see us taking a significant leap towards a data-driven, multimodal approach to detecting disease.

Craig Venter PhD is founder and CEO of the J Craig Venter Institute

CBD standards for munchies
The Food Standards Agency has mandated that any edible products containing cannabidiol (known as CBD) must make a valid authorisation application by the end of March 2021. These applications will require businesses to provide the details of the production process, clinical data and more.

Big pharma will tune in to the potential of psychedelics

Mainstream mental-health care will embrace alternative active substances such as psilocybin

By **Robin Carhart-Harris**

PSYCHEDELIC MEDICINE WILL BEGIN TO CROSS OVER INTO the mental health mainstream in 2021. In both Europe and the US, medicines regulators have eased restrictions on using MDMA to treat post-traumatic disorder (PTSD), and on psilocybin – the active substance in magic mushrooms – to treat depression. 2021 will bring new clinical trials, as support for the use of psychedelics in medicine continues to gain momentum.

Clinical research into psychedelics has boomed in the past five years and investors are taking note. The US Multidisciplinary Association for Psychedelic Studies (MAPS), which researches the topic, reached a $30 million (£23 million) fundraising target in 2020, on top of $80m of historical funds. This money will enable the completion of a phase-3 trial in the use of MDMA to treat PTSD, which will be necessary to achieve Food and Drug Administration approval. In the UK, London-based mental-health care company COMPASS Pathways has raised more than $115m to fund its efforts and bring to market a psilocybin treatment for depression. In August, the company filed an application to issue an IPO on the Nasdaq.

One barrier to the use of psychedelics in medicine is government regulation. The 1971 United Nations Convention on Psychotropic Substances placed psychedelics in its most restrictive category, Schedule 1, above drugs such as fentanyl, methamphetamine and cocaine. Legal-access loopholes exist in pockets of Europe and the Americas, but now governments are being increasingly lobbied to revise what many see as out-of-date policies. In November 2020, after The WIRED World goes to press, a ballot measure could see legal, regulated psilocybin therapy approved in Oregon.

Robin Carhart-Harris is head of the Centre for Psychedelic Research at Imperial College, London

It is important not to underestimate the effect of drugs such as psilocybin. In a study we carried out at Imperial College London's Centre for Psychedelic Research, which I head, 100 per cent of participants ranked a 25mg psilocybin experience as the single most intense state of consciousness of their lives. Because of this, 2021 will see the arrival of smartphone apps for those who use psychedelics, which will focus on harm reduction, including an app being developed by Imperial called MyDelica.

We are launching this app not only because of concerns about the growth of psychedelic misuse, but also the need to establish guidelines for their safe use, and to help with ongoing research. Without these, psychedelics might no longer show the same safety and efficacy that we've become accustomed to seeing from controlled research, and set back progress.

In 2021, big pharma could also enter the psychedelic space, as we continue to understand the drawbacks of treatments such as selective serotonin reuptake inhibitors (SSRIs). Since they were introduced to the market in 1987, SSRIs have been hugely profitable for pharmaceutical companies, but their efficacy and safety continue to be questioned. In one clinical trial of 59 individuals with a major depressive disorder, which we completed in 2020, we compared 43 daily doses of the SSRI antidepressant escitalopram with just two 25mg doses of psilocybin – plus equivalent psychological support for each condition. The results will be published in early 2021. As patents on many conventional antidepressants begin to expire – and public and regulatory opinion regarding psychedelics is changing – 2021 will be the time that psychedelic therapy casts a spotlight on the limitations of current mental-health care treatments, and highlights a bold alternative.

Taking the sting out of malaria The results of a trial into the efficacy and safety of Mosquirix, the world's only vaccine against malaria, will be published in 2021. Mosquirix stimulates an immune response against a protein that occurs on the surface of the spore cells of the malaria-causing parasite *Plasmodium falciparum*. The vaccine's side-effects are still a concern.

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UK consumers will be paid to use clean power

Using surplus renewable energy during off-peak hours will change our habits

By **Roisin Quinn**

ZERO-CARBON POWER OUTSTRIPPED fossil fuel in the UK's electricity mix in 2020 for the first time since the industrial revolution. Back then, Thomas Edison's Holborn Viaduct coal plant – opened in 1882 and the world's first coal-fired power station – could light 1,000 lamps. Today, a single rotation of a wind turbine off Scotland's coast can power a home for a day.

The challenge of green power is that while we humans are creatures of routine – we get up, travel and cook at the same time, creating predictable peaks and troughs in demand – wind and sunshine can show up at unexpected times or not at all. This causes fluctuations in power that our engineers at National Grid Electricity System Operator (ESO) must smooth out by balancing supply and demand in real time.

But consumers also have their part to play in this balancing act. Time-of-use energy tariffs, which incentivise people to use electricity outside those predictable peaks, will help keep the grid in equilibrium. And, in 2021, customers who sign up to them will be rewarded for their efforts.

Energy suppliers are already experimenting with time-of-use tariffs, which track electricity prices on the wholesale market. As periods of low demand and high renewable generation send market prices negative – something we have seen more than 250 times already during 2020 – consumers will be compensated for soaking up excess clean power.

During the 2020 May bank holidays, Octopus, a sustainable energy firm based in the UK, invited 50,000 customers to take part in a trial of its Agile Octopus tariff's "plunge pricing". High renewable output coupled with low demand as a result of lockdown pushed prices below zero and participants were paid between 2p and 5p per kWh to move their energy use into off-peak windows. Those who took part in the trial used an additional 71MWh in those periods – the equivalent of 10,000 electric cars charging for an hour – and eight times more power than those in a control group. It showed that even modest price incentives drive behavioural change.

In 2021, we will see more suppliers innovating to encourage us to think about how (and when) we consume electricity. According to our own research, there are likely to be half-a-million electric cars on Britain's roads in 2021 – more than double today's numbers. This will drive uptake of smart charging linked to time-of-use tariffs.

Energy storage will amplify the effect – 700MW of battery capacity on the electricity system is already absorbing excess power when demand is low and discharging at peak time. And once vehicle-to-grid technology has matured, an electric car's battery will push energy back into the network, too – unlocking some 40GW of flexible capacity.

As our demand becomes smarter and we change our habits to exploit green energy, we can more easily balance a renewable-rich grid. Our ambition at ESO is to operate an electricity system with zero carbon by 2025. The choices consumers make in 2021 – and the financial incentives they are offered by suppliers – could help make that a reality.

Roisin Quinn is Head of National Control and Chief Engineer at National Grid Electricity System Operator

Recycling must get resilient

A robust, circular approach to waste will be needed in 2021

By **Sameh Wahba** and **Silpa Kaza**

WE ESTIMATE THAT IN 2016, THE WORLD generated 2.01bn tonnes of household waste per year. Waste generation is set to increase by more than 70 per cent, to 3.40bn tonnes, by 2050, more than double the estimated population growth rate, pointing to a real crisis.

In general, the volume of waste generation per capita increases as countries become more prosperous; the richer we are, the more we consume. But there seems to be a trend of decoupling between waste production and prosperity beyond a certain income level. High income countries (with average individual incomes above roughly $80,000 annually) are trending towards lower volumes of waste production and disposal. Countries such as South Korea, for example, have introduced financial incentives to reduce waste and recycle more. In 2021, we will have to maintain this trend – and extend it to lower-income countries.

But, during the Covid-19 crisis, single-use plastics have proliferated. They're used in packaging to improve safety, by food delivery services and in medical equipment. We have also seen a reduction in good waste-management practices. From Miami in the US to the Bantar Gebang landfill in Indonesia, recycling has halted to limit workers' contact with waste – or because of a reduced workforce. Many cities have paused plastic-bag bans or charges. And informal waste picking everywhere has declined as pickers try to avoid Covid-19 exposure during waste collection.

In 2021, the resurgence of single-use plastics will continue, with high consumer demand for protective gear and heavily packaged products and food, and increased use of plastics in hospitals and public facilities. These plastics have limited recycling capability and will lead to higher contamination of rivers and oceans.

The need to simultaneously address global waste and the pandemic offers an opportunity to decouple growth from waste by putting in place sustainable waste-management systems and moving towards a more circular approach to its reduction. Promising private-sector initiatives are underway through pooled funding and blended financing, experimentation across the waste-management value chain and digitisation. Circulate Capital is one of a number of funds investing in sustainable waste-management systems in various countries to improve recycling and support a circular approach. London-based startup ReCircle is developing ways to reclaim raw materials from waste to go back into manufacturing. In 2021, by considering local organics-management options, encouraging use of recyclable materials and increasing the number of schemes across the world that focus on waste prevention, governments will help keep cities healthy and safe while also saving money and reducing landfill.

Sameh Wahba is global director for Urban, Resilience and Land at the World Bank

Silpa Kaza is an urban specialist at the World Bank's Urban, Resilience and Land Global Practice

Cleantech will help boost the economy

In 2021, a boom in green energy will lead us out of a Covid-19 downturn, while building a sustainable future

By **Hayden Wood**

IN 2021, GOVERNMENTS WILL BE WRESTLING WITH THE economic downturn caused by Covid-19 and they will face significant pressure to include in their recovery plans and measures to reduce the rate of global warming.

An Ipsos poll conducted in April 2020 found that 71 per cent of people surveyed across 14 mostly affluent countries felt that climate change was as serious a crisis as the pandemic. Research by my own company, Bulb, has shown that more than a third of the UK public lived more sustainably during the lockdown.

The challenge for 2021 will be to ensure that support for climate-friendly policies continues to grow and that intentions are transformed into long-term actions. Ipsos also found that, despite their stated concern about the environment, people were on the whole no more likely to make changes to their own environmental behaviours than when they were last polled in 2014. And only a quarter of the people we spoke to intended to continue their new, eco-friendly habits as we move into a post-Covid world.

Governments will have a key role in turning this situation around and ensuring more people make more sustainable choices. It won't be easy during an economic recession, but I am optimistic we will make significant strides in this direction. In the UK, the Council for Sustainable Business – established in June 2020 and with which I'm involved – created a series of 14 commitments for British businesses to sign up to, covering topics such as reducing greenhouse-gas emissions and increased support for biodiversity. We've already seen many businesses stand behind these pledges.

The dynamics of the energy market itself can also make a difference. In the past five years, the proportion of UK consumers choosing a renewable tariff has risen from one per cent to more than ten. And that demand has forced providers to generate more renewable energy. For the first time in 2020, renewable power contributed a bigger share – about 40 per cent – of the European generation mix than fossil fuels, which provided 34 per cent. And the UK went coal-free for a record two months in 2020.

There were many reasons for this, not least the reduction in energy demand caused by the pandemic, but it has provided us with a glimpse of what a truly climate-friendly energy market could look like. And developing that market offers economies a huge opportunity to innovate and become world leaders in cleantech.

I am confident that, in 2021, public pressure will force governments and businesses into committing to and enacting more sustainable policies, not only in the energy sector, but in all aspects of the way we use the planet's resources. The delayed 26th UN conference on climate change, or COP26, will be held in Glasgow in 2021 and will reignite the conversation. The climate crisis is a reality – but addressing it could also fuel our economic recovery.

Hayden Wood is CEO of Bulb

Cities rebrand as climate refuges

Metropolises will compete to entice migrants from under-pressure areas of the world

By **Emma Bryce**

NESTLED IN BANGLADESH'S BAY of Bengal, the industrial port city Mongla is steadily preparing itself for climate change. The mayor has built flood defences against rising tides, planted several thousand shade trees and installed a city-wide loudspeaker system that informs residents when extreme weather is afoot. These features are designed to protect Mongla's current residents, but they're also part of a wider plan to transform the city into an attractive destination for Bangladesh's climate migrants – those who are being displaced along the country's ravaged coastline by rising sea levels and storms. According to Sarder Shafiqur Alam, an adviser to the city's mayor, in 2021, Mongla aims to make itself even more "migrant-friendly", with plans for new educational facilities, housing and jobs.

This is one of a number of Bangladesh cities preparing themselves to receive climate migrants. In 2020, almost four million Bangladeshis were uprooted from their homes by extreme weather. Most end up heading for the sprawling, overburdened capital city, Dhaka. But researchers in Bangladesh have been investigating how cities like Mongla and the south-western city of Khulna, can be redesigned as refuges, providing jobs and resilient green infrastructure – and ease the burden on Dhaka. For these so-called "secondary cities", climate migration also presents a chance for economic revival, "an opportunity to rebuild and rethink", says Tasneem Siddiqui, the founder of the Refugee and Migratory Movements Research Unit in Dhaka, one of the organisations leading the research.

Bangladesh's geography and expanding population make it exceptionally vulnerable to climate change. Yet it's not the only country thinking about how its cities can play into the solution – and benefit in the process. By 2050, an estimated 25 million to one billion people will be on the move globally because of extreme conditions related to climate change – whether that's sea level rise, storms, drought or unlivable heat. For most, cities will be their final destination. In the UK, coastal Wales is pondering what to do with its first potential climate migrants, who are threatened by sea-level rise. In the United States, Texas alone is projected to receive almost 1.5 million new migrants by 2100 as people try to escape extreme weather in other states, including Florida and Louisiana. In 2021, pressure will grow for urban transformation to meet this escalating need.

Cities are already developing mechanisms for that. In 2019, a coalition of ten cities – including Los Angeles, Bristol, Freetown, Zurich, Kampala and Milan – formed the Mayors Migration Council to help city leaders translate international refugee and migration policies

Emma Bryce is a journalist based in London specialising in environmental and science writing

into action at the local level, which will benefit both the municipalities and the newcomers. From its inception, members recognised that climate change will be "front and centre" in driving urban migration, says Vittoria Zanuso, the Council's executive director.

Responding to that means different things for different cities. Some are starting simply by studying the terrain. The Canada-based Climate Migrants and Refugee Project is currently mapping climate displacement within, and into, the state of British Columbia, so it can give cities concrete recommendations on how to prepare. For others, transformation means ensuring equity for migrants by redesigning housing and transport systems and ensuring a greater diversity of jobs – as is the case in Bangladesh. In post-industrial cities seeking an economic boost, climate migrants also represent a huge chance for reform. As Zanuso puts it, "If people move there, there's an opportunity to revitalise by accessing funding for development that maybe they wouldn't have been able to before." The rust-belt city of Buffalo in New York State is currently positioning itself as a "climate refuge", based on modelling that shows that it will have a Goldilocks-style climate under future temperature projections. As a result, it is taking steps to make the area appealing to future migrants wanting to escape hotter, more unpredictable climes.

Meanwhile in Alaska – a state familiar with climate migration as homes are lost to coastal erosion and thawing permafrost – the city of Anchorage is trying to thread that understanding into its own migration policies, says Mara Kimmel, an immigration attorney and Anchorage's first lady. The city is trying to boost migrant inclusion through language programmes, equitable access to transport that connects migrants with housing and work and by matchmaking newcomers' skills with available jobs. Kimmel also believes migrants themselves carry a unique capacity for urban transformation – something impossible to measure, but beneficial to the cities that welcome them. "If we want to build resilience, one of the best ways you can do that is integrate people who have lived through shocks and stresses," she says. "The notion of survivability, and the skillsets that come with that, are things we have to start recognising."

So long to single-use
Costa Rica is banning use of polystyrene packaging and single-use plastic within the country's borders from 2021. In 2015, it declared it would be the world's first "carbon neutral" nation by 2021 – 99 per cent of the country's energy is from renewable sources already.

Ending edible waste will be an urban priority

We will make the food system more resilient by transforming our cities

By **Ellen MacArthur**

AT THE START OF THE COVID-19 PANDEMIC, empty supermarket shelves prompted people to ask – sometimes for the first time – where their food comes from. In 2021 we will see more food in cities provided by producers who are less vulnerable to the disruptions of long supply chains we experienced during 2020.

The pandemic caused consumers around the world to turn to smaller, local and regional food providers that could secure access to food during lockdowns. In the UK, the Farmers to Feed Us digital platform created new ways for small-scale food producers to provide fresh produce directly to consumers. Sales of food from community-supported agriculture (CSA), where consumers subscribe to receive in-season harvests from groups of UK farmers, increased by 111 per cent from February to April, with this trend also being apparent in the US and China. The 105-acre Eatwell Farm in California saw such a big spike in demand that it had to cease new subscriptions – and the waiting list is still growing. These demonstrate how producers can provide consumers with food security and, in return, how consumers have supported their businesses.

At the same time, accessing food hasn't been easy for everyone. Countless people around the world have been forced to turn to food donations. Meanwhile, when restaurants, schools and workplaces closed, food producers were hit with a lack of demand that saw tonnes of edible food go to waste. As income for smaller farmers was supported by consumer

demand, a decline in business from food-service providers has made their futures uncertain. With the food system's vulnerabilities exposed, the question has become: how can we better connect communities and food producers to make sure we are more resilient to future shocks? In 2021, the relationship between food and our cities will be drastically reimagined to answer this question.

Half of the world's population currently live in cities and, by 2050, 80 per cent of the world's food will be eaten in densely populated urban environments. But, as cities strive to become more resilient, they will become much more than centres of consumption. To become stronger in the face of unplanned disruptions, our cities and their surrounding areas will increasingly supply food and make use of valuable nutrients, creating thriving local, regional and international food networks. This will be a pivotal step towards a circular economy for food, in which nothing becomes waste, everything has value and the way we produce food regenerates natural ecosystems.

Increasing the amount of food grown in and around cities will also help to secure supply to residents without access to CSA schemes in nearby fields. Singapore, for example, imports a large proportion of its food, with only one per cent of its land being dedicated to agriculture. When the country's food supply chain was disrupted during its coronavirus outbreak, consumers in Singapore turned to urban farms and the government began to identify unused spaces in its cities for agricultural development. Similar developments to produce food locally will also be seen elsewhere in 2021. In Detroit, plans for a CSA programme are currently being shaped, while in France, the remaining two-thirds of Europe's largest urban farm, Nature Urbaine, will be planted in Paris, while 50 plots in Nantes that once grew flowers will provide vegetables for 1,000 households in need.

Ellen MacArthur is founder and chair of trustees of the Ellen MacArthur Foundation

Food producers will also adopt regenerative practices, which focus on outcomes such as healthy soil and carbon capture that tackles climate change, to build resilience into their operations. And cities will have a key role to play in this.

In the current food system, when food flows into cities, organic waste is created in the form of discarded produce, by-products and sewage. This waste is full of nutrients that can be used to grow new food and create biomaterials, but in today's system it is more likely to end up in landfill or go untreated. However, there are more viable – and greener – alternatives. In Italy, paper is already being made from pasta by-products, while orange peels, grape skins and excess milk are being turned into fabrics. In the UK, London has committed to ensuring that by 2026 no biodegradable or recyclable waste will be sent to landfill.

This shift will not only be driven by a need to address waste and pollution. As we look to recover from the economic shock of Covid-19, our analysis has shown there is an economic opportunity worth $700 billion (£538 billion) for cities to reduce edible food waste and use by-products. Less than two per cent of organic waste in cities is currently returned to the soil, yet the more organic matter that's within soil, the more water it can hold and retain, making crops resilient to disturbances such as droughts and floods. This applies whether food is grown in the city, its peri-urban surroundings or on rural farmland.

As part of the European Green Deal, the EU's Farm to Fork strategy is aiming to reduce use of synthetic fertilisers by at least 20 per cent and triple the amount of land farmed organically by 2030, as well as promising legally binding targets to reduce food waste. To meet these targets, cities will be expanding their organic waste collection schemes in 2021 and ensuring it is used effectively, putting it back on the land as a replacement for synthetic fertilisers, using it as compost to build organic matter in soil and to feed livestock.

These kinds of initiative will give cities a surer footing for the future. In 2021, we will begin to build a resilient circular economy for food.

In Italy, paper is already being made from pasta by-products, while orange peels, grape skins and excess milk are being turned into fabrics

Burial rites reimagined
The world's first human-composting site will open in the US state of Washington in 2021, after the legal go-ahead was given in 2020. Seattle-based company Recompose intends to combine the bodies of the deceased with wood chips, alfalfa and hay, to transform them into soil within 30 days.

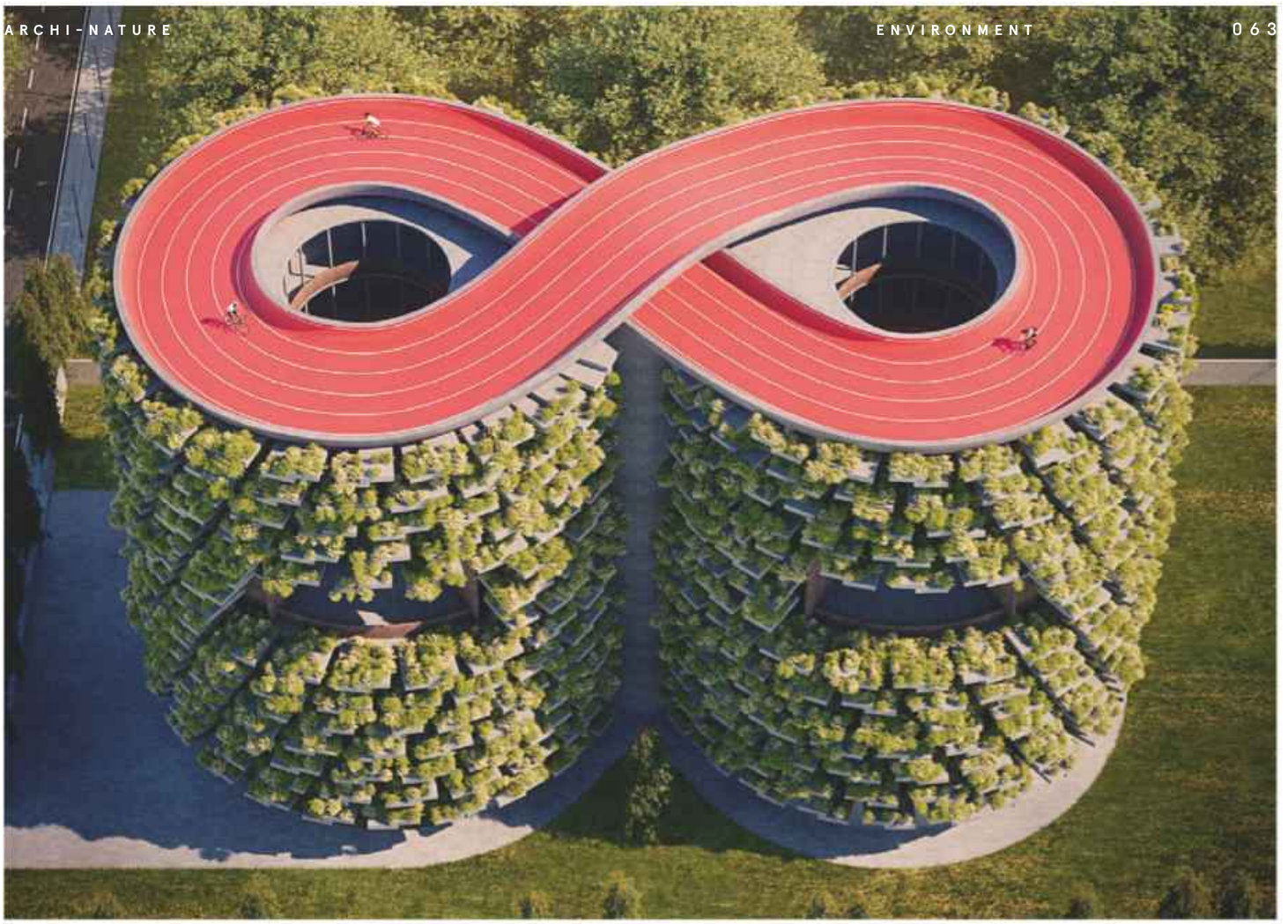
Biophilic buildings

By Sanjana Varghese

As sustainability and environmental issues start to assume a greater role in the considerations of architects and developers, it appears the age of the megabuilding may finally be over. Taking their place in 2021 are new, biophilic structures – from a school in India to an aquarium in Mexico and a hotel on a glacier – which incorporate elements of the natural world into their architecture, from sympathetic materials and forms to forging direct connections with their surrounding environments.

1. Svart Hotel, Meløy, Norway
Svart Hotel, built by Oslo-based architects Snohetta on the Svartisen glacier, north of the Arctic circle, will welcome its first guests in 2021. The hotel will use 85 per cent less energy than a comparable property thanks to the inclusion of solar panels and a series of channels cut through its roof that conduct light and heat into the interior. *svart.no*

2. Sea of Cortez Aquarium, Mazatlán, Mexico
Designed by Mexican architects Tatiana Bilbao Estudio, the Sea of Cortez is scheduled to open in summer 2021, in Mazatlán, just south of the Gulf of California. Its staggered structure is inspired by the idea of ruins being reclaimed by nature. Concrete walls of different sizes will act as vertical gardens for indigenous flora. *tatianabilbao.com*



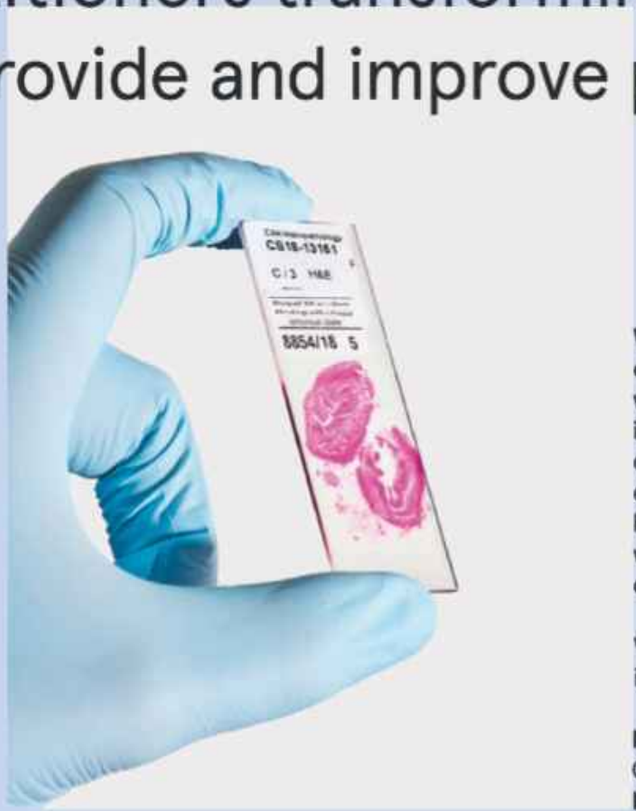
3. Forest School, Pune, India
Work starts in 2021 on a new school in Pune, western India, which will bring together the man-made and the natural. Designed by Mumbai-based studio Nudes, the school will be covered in greenery to create what its architects call a "living skin" that will keep the interior cool and help the building blend in with its surroundings. *nudeoffices.com*

4. Sluishuis, Amsterdam, The Netherlands
A 46,000 sq m residential complex on the water in IJburg, Amsterdam, Sluishuis will comprise 380 zero-energy residences, floating gardens and space for 30 houseboats. Designed by Danish firm Bjarke Ingels Group and Dutch architects Barcode, the complex will feature solar panels, triple-glazed windows and user-responsive heating. *sluishuis.nl*

5. Tropicalia, Rang-du-Fliers, France
Situated in the Pas de Calais, France, Tropicalia will be the world's largest tropical greenhouse. It will cover 20,000 sq m and include a kilometre-long walking trail through a range of tropical environments. The project, by Lille-based architects Coldefy & Associés, will feature a double dome that is designed to recycle heat back into the interior. *caau.fr*

Mapping the future of health

WIRED Health explores what's coming next for healthcare, highlighting the thought-provoking disruptors, scientists and practitioners transforming how we access, provide and improve patient care.



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E-mobility enters the mainstream

From scooters to delivery robots, cities will switch on to electric transportation

By **Lucy Yu**

THE STARTUP WORLD LIKES TO CELEBRATE exciting new technologies, such as AI and autonomous vehicles. But these are newcomers to the party compared to the electric motor, whose precursor technology celebrates its 200th birthday in 2021. Yet today, mobility overwhelmingly runs on fossil fuels. Electric-powered vehicles have been confined to the wealthy, the geeky and the green – not sufficiently affordable, accessible or practical for everyone else. In 2021, startups and industry disruptors will proliferate, heralding a new era of e-mobility for all of us.

The driver for this is, of course, climate change. Over 77 countries and more than 100 of the world's biggest cities have committed to achieving net-zero emissions. Globally, transport is one of the largest sources of CO_2 and other greenhouse-gas emissions. Governments have imposed future bans on the sale of petrol and diesel-powered vehicles, incentivising more electric-vehicle purchases and taxing the most polluting vehicles, but investors are also keen to accelerate the global shift from pump to plug.

In January 2020, London-based startup Arrival became an electric-first unicorn, attracting sizeable funding from established automakers. Its light commercial vehicles, including buses, vans and delivery robots, will be assembled by a planned network of 1,000 global "microfactories". In July, Tesla overtook Toyota to become the world's most valuable carmaker, and Chinese electric-vehicle startup Li Auto raised over $1bn from its IPO.

Though cars of the future may be captivating markets and the media, the electric revolution won't be limited just to our roads. In June 2020, the Velis Electro, made by Slovenian aviation startup Pipistrel, became the world's first type-certified electric aircraft. France has earmarked €1.5 billion in R&D funding for the development of electric and low-emission aircraft. And the UK government has announced the creation of a new Jet Zero Council, whose goal is making zero-emission flights a reality within a generation.

In 2021 we will also see a huge increase in the number of electric micro vehicles on our roads. Powered by green energy and with shared fleets, e-bikes and e-scooters will transform urban mobility. City leaders have declared their commitment to a "green recovery" from Covid-19, prioritising enhancements to infrastructure to welcome these modes as new, sustainable elements of local transport systems. While many modes have suffered loss of ridership during the pandemic, McKinsey is forecasting a rapid recovery for e-micromobility, returning to pre-crisis levels of travel. Infrastructure changes will only increase its penetration of the market.

Challenges remain. E-mobility networks require continuing investment in infrastructure and multi-agency co-operation. Greater use of clean energy is essential to guarantee system-wide emissions savings. Improved battery energy density will open up the auto market, but the prospect of long-haul battery electric flight remains some way away.

But while these issues and others, such as future models of ownership and use of vehicles, and how these will dovetail with technologies such as autonomy will take time to resolve, 2021 will be the year that e-mobility finally enters the mainstream.

Lucy Yu is director of public policy at the electric-scooter startup Voi

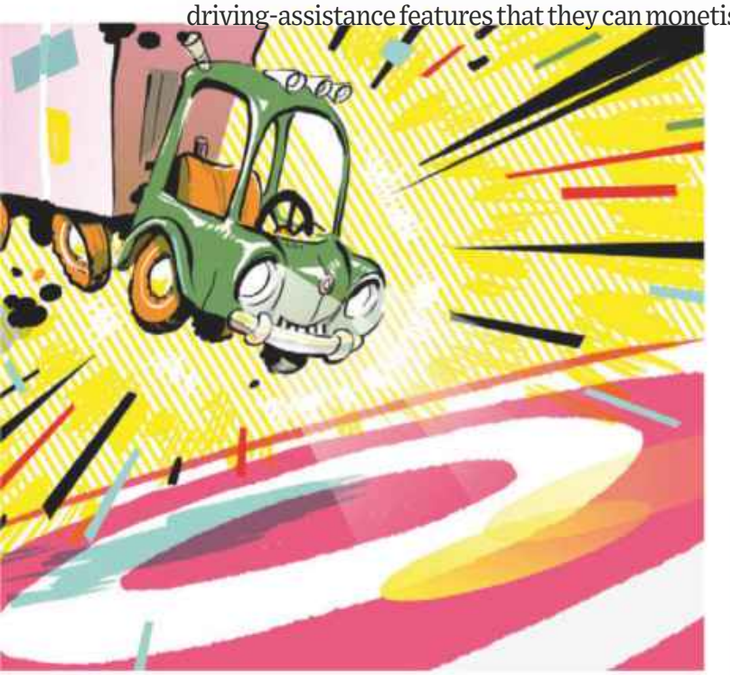
Autonomous driving will finally find its market

A convincing use case for driverless vehicles will at last emerge in 2021

By **Stan Boland**

FINDING THE PRODUCT-MARKET FIT FOR any new technology always involves trial and error: autonomous driving has so far has swallowed an estimated $50bn in investment with relatively little to show in return. In 2021 we will see autonomous driving finally find its fit – and it's not in personal travel.

Billed as the first everyday consumer application of AI, self-driving has simultaneously inspired its champions and proved a worry for its investors. Aiming high in terms of functionality has delivered plenty of exciting business cases, but the science and engineering problems they entail are not easily soluble. Aiming low has not delivered business cases that make sense and deliver a return. This conundrum has sent technology companies in a number of exciting directions, whereas automotive firms have ended up favouring simpler driving-assistance features that they can monetise more easily.



Stan Boland is CEO and co-founder of Five

In 2021, we'll see the first fruits of precise product targeting by well-funded tech firms.

In the trucking sector, companies such as San Diego-based TuSimple, Alphabet's Waymo and Aurora in San Francisco will start to sell their "drivers" to logistics operators. These will carry cargo, fully autonomously, from hub to hub over US highways, promising real savings in cost and time. At the other end of deliveries, robotics company Nuro, based in Mountain View, will move from last-mile trials with US retailers Kroger and CVS, into fully fledged, paid-for autonomous delivery services. We'll see similar use cases in China using Baidu's self-driving software.

There are two reasons why these applications of self-driving technology will find product-market fit.

The first is the pandemic, which has squeezed ten years of e-commerce growth into a few months. Consumer demand for home deliveries, groceries and other errands has been established and business cases predicated on home deliveries – and moving cargo around to support them – have been transformed.

The second is that the technology now exists to speed up the development and safety assurance of autonomous-driving technology. Virtual development and testing won't fully replace real-world testing, but, in 2021, it will make it easier for developers to find and fix bugs, improve performance and explore how software interacts with complex conditions such as environment, road layouts and human behaviours. My own company, Five, uses cloud-based software that can be hyper-scaled, making it possible to advocate for the safety of specific self-driving applications.

In 2020, the new services that launch will attract capital from across the autonomous-driving sector, and will spur automotive companies to move faster towards "full" self-driving applications to keep up. We will see a combination of proven technology and real-world market fit take a step forward into environments where self-driving vehicles are finally ubiquitous.

We will see the end of supply-chain optimisation

In 2021, just-in-time thinking will be yesterday's business strategy

By **Bridget Rosewell**

AS THE PANDEMIC HAS REVEALED, while global trade worked well when trade routes were running smoothly, disruptions to them can lead to chaos. In a 2018 report on the future of food supply chains, for example, the consultancy ARUP found that only eight per cent of companies in the sector believed that they had a genuinely agile supply chain that could respond to disruption quickly.

In 2021, we will see the long supply chains and just-in-time principles of manufacturing and retail turned on their heads. And, as global supply chains continue to be disrupted by the pandemic, we will also change our attitudes to the idea of repairing rather than replacing goods.

Technology has already improved the way we move things between our cities and states. Pressures to reduce the carbon emissions of freight have led to better route planning, lower fuel costs and more intelligent use of different and less-polluting delivery mechanisms. Companies such as DHL and UPS have been at the forefront of this trend, investing in logistics startups and working on in-house innovations, such as indoor robots and an online platform for freight forwarding. In 2021, we will see this trend continue.

Drones and robotics will also have a small role to play in improving delivery mechanisms. In 2020, Amazon expanded its trial of Amazon Scout delivery robots in the US to two more cities. And, in 2021, San Francisco-based Starship Technologies, which is already running trials of autonomous delivery robots in Washington, DC, Irvine, California, and Milton Keynes in the UK, plans to expand to 100 US universities.

Despite these advances, we won't, however, see the end of human delivery drivers just yet. Costs and challenges around management will preclude drones and robots from becoming the norm. In the UK, regulations around where drones can and can't be flown could reduce their uptake. And not all delivery robots are as yet smart enough to be able to adapt to some of the challenges of real-world cities. In Milton Keynes, one of Starship Technologies' robots fell into a canal.

In manufacturing, the core technology – 3D printing – that was heralded in its early days as a kind of superheated version of the just-in-time system, will expand, but it, like drones and robots, is also proving slow to live up to its promise. Many sectors have concerns about the speed of 3D printing and whether 3D-printed parts will be reliable.

As we wait for technology to catch up with our needs (and for the disruption caused by the pandemic to end) we will discover other ways to make supply chains more robust. These will include a new emphasis on repairing items rather than replacing them. Responding to consumer concerns about the high level of electronic waste in the world, some companies are now moving in this direction. In 2020, Amsterdam-based Fairphone launched the Fairphone 3+ smartphone, which can easily be repaired and upgraded by the user. In 2021, we will see other companies entering this sector.

We will use technology to improve the way we manufacture goods and move them around the world – and we will, I hope, change our attitude towards replacing items and instead look to repairing them. The pandemic has revealed the fragility of the supply chains the developed world has relied on for decades. Changing the ways we manage them will be key to creating a more sustainable world and a thriving economy.

Bridget Rosewell is commissioner at the UK's National Infrastructure Commission

Covid-19 will drive reform in paratransit infrastructure

2021 will see a more formalised public-transport system in many African cities

By **Astrid Haas**

Air travel takes off once again Demand for air travel will spike in 2021, according to the International Air Transport Association, but won't return to 2019 levels.

DURING THE HEIGHT OF THE 2020 pandemic, the authorities in many African cities temporarily banned vehicles that make up the semi-official paratransit sector – such as the taxis (14-seater minibuses) and boda-bodas (motorbike taxis), that provide an essential service in my own city, Kampala – fearing that they would be vectors of Covid-19 transmission. In 2021, they will use this opportunity to reform the paratransit sector to make it more efficient, reliable and customer-friendly.

The paratransit sector provides an essential link between homes and places of work for those, usually the poorer residents of a city, who cannot afford cars but whose place of employment may be too far to access on foot. A major barrier to reform has been a lack of support from those who work in the sector, but governments now have a chance – thanks to the pandemic – to start reforming the sector with reduced political pain. They will do this through better regulation. In Kampala, the city's government has used the opportunity presented by lockdown to start registering the boda-boda and taxi industry, with providers required to apply for and obtain an operating licence.

Technology will also have a major role to play. Ride-hailing apps, such as Uber, Bolt and Taxify have already disrupted the African transportation sector. In a post-pandemic world, city governments are more likely to tap into the potential these apps have demonstrated. Apps will not only be used to support the formalisation and management of the industry through registering vehicles and determining routes, but they will also allow customers to connect to riders and drivers contactlessly. Cities such as Kigali in Rwanda have already instituted transport regulations that require all boda-bodas to use GPS-enabled smart meters to find their customers and determine their fares. Customers will have to pay using mobile money. In 2021, other cities (including Kampala) are likely to introduce similar measures.

This process of formalisation, while providing a better service, could be reflected in a higher price for users. In Accra, Ghana, for example, government and vehicle owners have already agreed a 15 per cent fare increase to compensate for the fact that vehicles cannot operate to full capacity. This increase is fully passed on to consumers and it is likely that this will be the case with other reforms, too. However, governments will need to careful to ensure that any proposed reforms do not stifle an industry that has otherwise been providing employment, is generally innovative, largely self-financing and which provides an essential service for many African citizens.

Astrid Haas is the policy director of the International Growth Centre in Kampala

Car-pooling will help cities break their dependence on single-occupancy vehicles

The pandemic gave us a glimpse of low-traffic cities. In 2021, we'll try to make this permanent

By **Noam Bardin**

Noam Bardin is CEO of Waze, and was previously VP of product at Google

OVER THE PAST DECADE, WE'VE SEEN A GLOBAL awakening to the broken transportation systems that we rely on. Single-occupancy vehicles (SOVs) are consuming cities, with traffic levels continuing to rise, leading to air pollution that harms our communities, the environment and economies. Regardless of how many roads are built to keep up with the increase of vehicles, we cannot "pave" our way to better transportation habits. In 2021, cities will wake up to the effects of vehicle dependence, and will respond by nudging people toward alternative transport solutions, such as publicly shared bikes and scooters, and carpooling – which will be key to solving our cities' transport problems.

Carpooling is a huge opportunity to reduce the amount of vehicles on our roads and a number of companies, including Waze, have developed platforms in this area. By filling all five seats in a car, we could transport the same number of people with 20 per cent of the infrastructure, pollution, cost and congestion.

The Covid-19 lockdowns gave us a glimpse of what a world without SOVs could look like. At Waze, we saw daily driven kilometres reduce by as much as 60 per cent globally in April compared to February, with the remaining cars on the road flowing freely. Cities such as Toronto, Paris, London and my hometown of New York built on these changes by pedestrianising streets, creating bike lanes and even opening restaurants in car parks.

However, post-lockdown trends seem to suggest that a future of efficient transport systems could now be further away than what we had originally hoped. We have seen a dramatic increase in the demand for cars, as people avoid public transport and look to use SOVs for both short- and long-distance transportation. This in turn has put financial pressures on public-transit infrastructure.

In 2021, we will need to create a "New Transportation Deal", which will rid us of our dependence on SOVs. Currently, authorities such as the US Centers for Disease Control and Prevention recommend carpooling with only one passenger, but it is hoped that this will ease as Covid-19 restrictions lift further.

To encourage ride sharing, local authorities will have to provide stronger incentives to encourage citizens to participate in journeys with others by increasing congestion pricing and expanding schemes such as dedicated lanes for high-occupancy vehicles. Governments will be required to introduce tax incentives for employers who adopt shared mobility and for the staff that use it.

The pandemic has given us a glimpse of a future in which our cities have far fewer vehicles on the road. In 2021, we will have to begin introducing policies that ensure this vision becomes a permanent reality.

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Remote working will challenge the very basis of states

Nomadic workers will upend the traditional tax and spend system

By **Kersti Kaljulaid**

IT TOOK A PANDEMIC FOR US TO REALISE that the world's 20th-century model of production, in which people huddled into large enterprises, honed specialities and shared their competences with co-workers, was no longer working. 2020 has shown that many people are able to study, work and organise their everyday life independently from their habitual geographical location. The online world has made borders redundant and this challenges the very nature of nation states. In 2021, states will have to respond.

So far states have been built on the idea that most people live at fixed addresses and work for specific employers. They and their employers pay taxes to the government, which redistributes them back through society – schools in people's neighbourhoods, doctors within a reasonably close distance to home, and so on. But if remote work and remote schooling function well when someone is outside these institutions, shouldn't they function just as well when they are on another continent? This will be a significant challenge for states, as it will threaten their established models of taxation and redistribution.

As distance working and learning pan out, we will see citizens living elsewhere in the world while still requiring their "home" governments to be safe havens, providing them with administrative and redistributive services. States will have to shift from a geographical definition to being providers of a "service pack" that is available to all their citizens wherever they happen to be.

So far most governments have failed to achieve this. They have been trying to fit the concept of a digital society into the framework of the industrial model. The year 2021, however, will be a turning point for many, if they want to succeed. If their own states are struggling, people will turn to more suitable and flexible solutions for them. Education, social security and many other necessary services can already be purchased from the global market. In doing this, though, many of these citizens will opt out of their state's taxation system.

This is a new world we are not prepared for. We have spent years in the Organisation for Economic Co-operation and Development for example, trying to negotiate a common agreement on how to tax companies that exist more online than in physical locations. It is not the likes of Facebook and Google – which are relatively stable entities – that we need to tax. Instead, we will need to find ways of taxing and serving those independent citizens who live, work and earn globally, and who don't feel the need to supply the relevant authorities with a permanent work or home address. They will agree to pay taxes to any government in the world only if they see a point in doing so.

At some point in their lives, those people may then choose to opt back into the system – and move back to their countries of origin – perhaps when they are older and in need of, for example, healthcare or education for their children. But, by then, the state will be short of the resources it needs to service them.

Unless we tackle this issue, we will see the opportunities of distance work unravelling the nation state, as individuals instead shop globally for a government that best suits their needs or that follows the values they ascribe to. This is not a matter of finding technical solutions to the problem – governments will have to adapt and turn the lessons we have learned in 2020 into a new idea of what a state is in 2021.

Kersti Kaljulaid is the president of the Republic of Estonia

Free expression gets threatened

State-sanctioned bodies will continue to suppress and subvert the open internet that we currently take for granted

By **Nighat Dad**

WE HAVE SEEN INCREASING ATTEMPTS by governments to suppress freedom of speech on the internet. TikTok has attracted the ire of US president Donald Trump, while Pakistan's state-run regulator has hinted once again at blocking YouTube after prior tussles with the live-streaming app Bogo and the ByteDance-owned gaming platform, *PUBG*. In 2021 we will see more governments threatening platforms for no other reason than they dislike their content.

According to Freedom House, which monitors civil liberties across the world, freedom of expression online continues to decline globally, with state surveillance, restricted internet access and a lack of effective resistance on the part of social-media companies cited as the major causes.

This trend is certain to continue. Co-operation between governments and social-media companies is likely to expand – but with even less transparency and independent oversight. Technology giants, such as Facebook and Google, in a bid to maintain their growing customer bases, will continue to establish community guidelines, privacy rules and data-collection mechanisms. These will be more in accordance with host countries' laws, however, than with a view to addressing users' legitimate concerns.

Governments will continue to attempt to regulate online spaces. This will often be portrayed as efforts to "contain" civil unrest, and, in the case of autocratic regimes, may lead to blocked social-media platforms and restricted internet access. We have already seen this happening in Belarus, Sudan, Bangladesh and Brazil, so expect others to follow suit in 2021.

Surveillance of citizens will also see an increase. In responding to the Covid-19 pandemic, many governments have used digital platforms to collect vast amounts of data to monitor and contain the spread of the disease. While this approach may be rationalised as a public-health imperative at present, it is likely that such scrutiny will continue long after the infection is brought under control.

Prohibiting access to information and denying freedom of expression go against the fundamental liberties of citizens. In 2021 we will have to acknowledge that the internet is not the free space it was originally envisaged to be. Online spaces are a fundamental part of our modern ecosystem, but we will need to discover ways to govern them more effectively, preserving freedom of expression and protecting the privacy and security of their users.

One way to achieve this will be to model good self-governance. Oversight boards – such as that set up by Facebook, of which I am a member – have a responsibility to hold their organisations accountable, and they will find themselves motivated to raise the ethical bar for competitors.

But consumers will make their opinions known too, gravitating away from the big players towards services, such as Signal, which they will see as a safer haven for their data.

In 2021, measures will be taken by individuals and countries that go directly against the core values of the internet, and these will increase in frequency and force. Only by establishing good governance and, if necessary, voting with our feet, will we be able to preserve this key part of our democratic life.

Nighat Dad is a lawyer and internet activist who runs the not-for-profit Digital Rights Foundation

We will integrate technology into the social contract between government and society

Building trust in how data is used will prepare us for the next crisis

By **Wendy Hall**

TECHNOLOGY, ESPECIALLY THE communications technology of the internet, has improved our lives enormously. But, around the world, we have seen an increase in its misuse. In 2021, the search will be on for ways to restore public trust in technology and (re)establish it as a force for good in the social contract between government and society.

Governments in a number of states are already using the internet to spread misinformation and suppress dissent. There have been many examples of technology failing to live up to our expectations as a way of managing Covid-19. We've seen this play out as we try to mitigate the effects of the pandemic too – such as the failure of the algorithm used to assign A Level grades in the UK in August 2020. The algorithm performed as it was designed to, but failures in the design and issues with data led to chaos and confusion for students, many of whom will remember this as one of their most formative experiences of technology.

In 2021 we will see increasing demand for a new kind of social contract, one which recognises the challenges and benefits that technology of all kinds brings to our daily lives, and ensures that governments must act responsibly when it comes to dealing with technology.

This move towards reining in governmental use of technology will be the result of public pressure. As the Cambridge Analytica scandals of 2018 and the growing concern over the UK's contact-tracing app show, people have become far more sceptical of what the government says it's doing with their data, especially during the pandemic. In April 2020, The Ada Lovelace Institute, which I chair, concluded that "effective deployment of technology to support the transition from the crisis will be contingent on public trust and confidence."

Governments will have to take steps to convince their citizens that they are worthy of their trust. To do this in the context of the pandemic, it will be essential that a publicly accountable body is set up to represent the rights of citizens in government use of data around Covid-19, particularly if there is the risk that these interventions develop in ways that reinforce the systemic inequalities that disproportionately impact the most vulnerable. Their oversight should include the technology governments are launching to deal with Covid-19, with legislation ensuring that these technological interventions, such as so-called immunity passports, are thoroughly vetted and are swiftly decommissioned when the need for them has passed.

There is a huge opportunity for a virtuous circle here. Greater trust of how governments use our data will lead to citizens being happier about handing over their data to governments in the first place. In turn, this will give us better data to feed into the algorithms we use to manage the crisis. In 2021, we will use the lessons we have learned through the pandemic to understand the complex and myriad ways in which technology is integral to every aspect of our lives and start to integrate it into the foundations of our society.

Wendy Hall is regius professor of computer science at the University of Southampton

In 2021, there will finally be a reckoning for women and work

Covid-19 provides a chance to make home and work life fairer

By **Sheryl Sandberg**

AS LONG AS WOMEN HAVE BEEN IN THE workforce, many have worked a "double shift" – performing a full-time job, then coming home and doing the vast majority of childcare and household tasks. According to research published by *The New York Times*, if women worldwide were compensated for this unpaid labour, they would have earned $10.9 trillion (£8.3 trillion) in 2019. In 2021, thanks to the pandemic, we will understand in a concrete way that this situation has to change.

According to research by Lean In, the organisation that I founded, when the pandemic began, the typical woman in the US working full time with a partner and children saw her daily responsibilities skyrocket. Suddenly, she was doing an average of three or more hours of household work, five or more hours of childcare and homeschooling, and an hour and a half caring for elderly or sick relatives – every day. And that's before she even began her professional work for the day. It wasn't a double shift anymore. It was a double-double shift.

Of course, the pandemic has forced men to do more, too. However, on average, working women with families were doing more than 20 hours of additional domestic labour every week than men. That adds up to half a full-time job.

Meanwhile, across the world, millions of women have careers in industries on the frontlines of the Covid-19 response, such as healthcare, pharmacy, food and housekeeping. Women make up two-thirds of the global health workforce, for example, and 85 per cent of nurses and midwives. Across OECD countries, they also account for 90 per cent of long-term care workers. Doing their job suddenly meant risking not just their health, but their families' health too.

On top of this, the pandemic has triggered a recession, with redundancies and furloughs that have sharply affected women. Women are also disproportionately represented in professions that have been affected by lockdown and social distancing measures, in sectors such as retail, air transport, food-and-beverage services and accommodation services. The impact has been so notable that it has been coined a "she-cession" by C Nicole Mason, president of the Institute for Women's Policy Research. In the US, Black women in particular have suffered; they are nearly twice as likely as white men to have lost

Sheryl Sandberg is COO of Facebook and the founder of LeanIn.org

a job or had their hours or pay cut.

Some countries have been able to safely open schools, childcare centres and workplaces, making life more manageable for working mothers. In others, reopening has been more difficult. The result is an ongoing economic and health catastrophe for women, who are pushing themselves to the brink day after day. It's not sustainable.

In 2021, we will have the chance to reflect on how the pandemic has exposed the unequal burdens women carry. Families, employers and policymakers will at last have to grapple with hard questions that should have been answered long ago. How should we value the invisible labour women do for families every day? Can we finally get rid of the outdated notion that caring for children and running a household are inherently "women's work"? How can employers do a better job of supporting women – and particularly women of colour, who often receive less support and fewer opportunities at work? What will it take to close the gender and racial pay gaps once and for all? What government policies would make a real difference for women and families?

Since the pandemic began, I've heard from women who are having conversations with their husbands for the first time about the division of labour at home, and from employers who are striving to be as flexible and accommodating toward working parents as possible. That gives me hope that real change will come out of this difficult time.

There's an expression in politics: never let a good crisis go to waste. The crisis of Covid-19 is giving us a chance to make our homes and workplaces fairer for women and everyone. In 2021, we will see that we can't let this opportunity pass us by.

Social media's copyright clash
In June 2021, the EU will implement reforms to the EU Copyright Directive, which hold companies accountable for failing to remove copyrighted content, such as memes. The EU has proposed tweaks to dispel concerns about the effect of this on social media, but Google and social-media platforms are not in favour of the changes.

Disaggregated data will bring justice for all

Public policy-making will be made more effective by analysing the intersection of class, poverty and race

By **Rhonda Vonshay Sharpe**

AT THE BEGINNING OF THE CORONAVIRUS pandemic, our focus was on protecting those who were most vulnerable to Covid-19 – the elderly and people with comorbidities. As the months wore on and the virus lingered, our focus shifted from those with fragile health to the economically vulnerable.

In 2021, we will see the naming of at-risk populations and the demand that lawmakers construct policies to protect these groups. A vulnerable population is defined as one that is at greater risk of poor economic, educational, health and political status or outcomes. Predictably, the factors that cause a population to be exposed are rooted in institutional racism, systemic sexism and the often overlooked structural classism.

Structural classism describes the wedge between those who own the means of production and wealth and the working-class people who do the labour. It often colours the language that's typically used to describe the poor. When you intersect structural classism with institutional racism and systemic sexism, the net result is the criminalisation of the poor, a devaluing of low-wage workers and a widening of economic inequality.

In 2021, we will see academics, activists and grass-roots organisations unite to advocate for policies that provide workers with a living wage, paid leave and a pathway to wealth accumulation. These policies will have a central theme: the redistribution of wealth with the intent to reduce economic

inequality and increase economic security.

Economic insecurity will take centre stage as we enter 2021 in a recession. Politicians will blame each other for not enacting policies that prioritise the safety of frontline workers, renew consumer confidence or stabilise disruptions to the supply chain. As the death toll increases from Covid-19, we will hear a familiar term: "disproportionately" – this is code for how institutional racism and anti-Black policies have impacted Black, Hispanic and Indigenous communities.

We will also hear a new term, "disaggregated data" – in other words, data that has been divided into detailed sub-categories – which will allow us to understand who exactly Covid-19 has killed, who was denied or benefited from relief packages and who was completely forgotten. Disaggregated data will also allow for the identification of the nuances in the characteristics and outcomes that define vulnerability. We will require that data be collected and reported with the purpose of being separated into its component parts. This will give us the accountability we need to measure progress in the wellbeing of vulnerable populations.

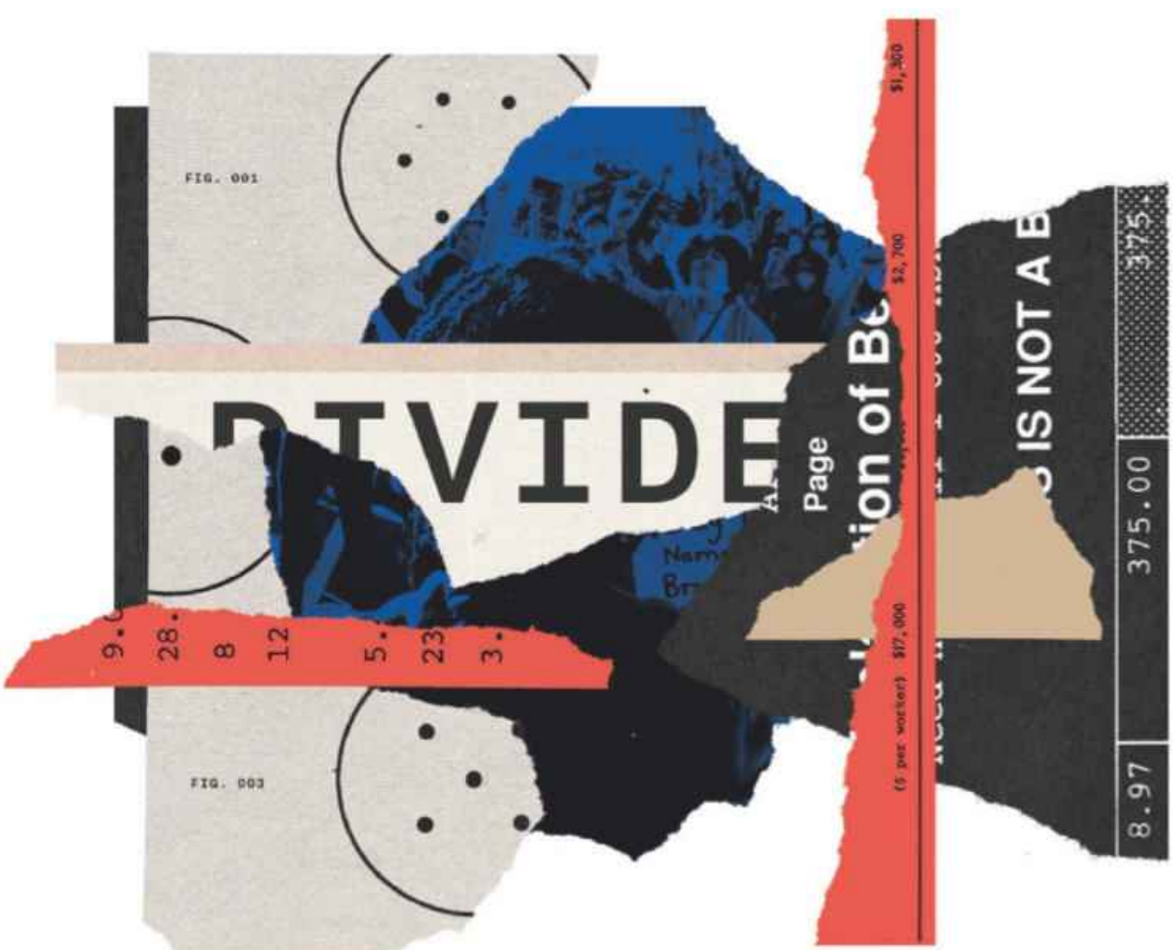
In 2021, policy-makers will learn what cancer researchers already know – that disaggregated data can inform policies to increase health and economic outcomes of vulnerable groups. While the discussion has focused on people, disaggregated data can also identify vulnerable industries and sectors. The beauty of the mechanics surrounding this process is that every person and business can see themselves in the data (and there will be plenty of data).

The lessons that policy-makers learn from Covid-19 will have an impact on the way they collect data, which new policies they enact, and what measures they take to protect populations most exposed to the virus. The pandemic will teach us that vulnerability is dynamic: think health versus economic. But we will also learn that framing policy by centring on the vulnerable can unite.

Many countries are experiencing deep divisions in their societies and global co-operation has reduced. The only hope for healing is to focus on those most at risk who have been under-served by social and economic policies for decades.

In 2021, we will see societies begin to address, in measurable ways, all of the "isms" and "phobias" that have debilitated our ability to respond adequately to crisis, preventing us from moving forward as a society that is equitable and inclusive.

Rhonda Vonshay Sharpe is founder and president of the Women's Institute for Science, Equity and Race



The WTO will place social concern at the heart of global trade

World economies will need to be more mindful of wealth redistribution

By **Bernice Lee**

JUST AS CLIMATE CHANGE WORSENS existing vulnerabilities such as food poverty and water shortages, trade amplifies weaknesses in the social fabric. In regions where people have fallen behind economically due to political neglect and technological change, it is jobs lost in the face of import competition that make the headlines. The appeal of Donald Trump and Brexit had much to do with deep grievances felt by those attributing their social problems to the negative impacts of openness and competition from shores afar.

Yet the costs of doing away with globalisation and our open-trading system could far exceed any benefits. This is why, in 2021, the World Trade Organization (WTO) will begin its metamorphosis into an organisation that puts social issues at its heart.

Economics 101 posits that trade creates winners and losers, but with all countries gaining overall. The economists were, and still are, right about this. Where they fell short was to assume that redistribution would happen. This now looks like magical thinking of the trickle-down era.

For the open global economy to survive, losers from technological change and trade must be compensated and empowered to benefit from new market conditions. The alternative will be to give up trade, which is a proven way for countries to earn hard currency that could help reduce poverty or secure critical supplies amid, for example, pandemics.

International institutions are often slow to change and the paralysis at the WTO has been exacerbated by US-China geopolitical strife. But in 2021 we will acknowledge that the benefits of global trade are still not felt where they are needed most. The viability of the multilateral trading system now depends on its ability to reduce pain on the economic margins of advanced economies, and tackle trade's discontents head-on.

Globalisation is in crisis and its future depends on a renegotiation of the social contract

To do this, member states will be asked to evaluate and report on their trade readiness not only from the economic vantage point of trade distortions, but also from the point of view of social dimensions. This will force politicians to be more honest about the gains and losses from trade and also about their distribution. It will also encourage more responsible action regarding supply chains, something we are already seeing in California, for example, with the Transparency in Supply Chains Act, which seeks to reduce modern slavery.

Closing borders would create new winners and losers, just as open markets have. The WTO cannot change this equation, but it can promote a more honest discourse on trade and encourage better use of domestic policies to mitigate social ills. It will also be able to lead in the establishment of a new global fund to address social-justice issues around trade and equity.

Globalisation is in crisis and its future depends on a renegotiation of the social contract. Trade is now a weapon of choice for many politicians, but we know from multiple surveys that younger generations are loath to forego concerns over equality, labour rights, the environment and gender parity. In 2021, the WTO will be key to placing social concerns at the heart of our debates about globalisation.

Bernice Lee is the executive director of the Hoffmann Centre for Sustainable Resource Economy

Communities get reconnected

Repurposed buildings will provide intergenerational homes

By Sarah Harper

FOR HUNDREDS OF YEARS, HUMAN BEINGS LIVED, WORKED and played in local, intergenerational communities. That changed when industrialisation lured young people to cities, leaving their families behind. In 2020, however, we returned to the former way of living. Across the globe, Covid-19 has changed how we interact with friends, family and co-workers, basing ourselves predominantly in our homes and streets, connecting with colleagues, shops and services over the internet.

In 2021 we will increasingly work and socialise in connected local communities. These groups of people will become the magnets for life's activities, as opposed to constructed developments that require people to travel to and from segregated activities.

Some of these drivers are pre-Covid, but they are likely to be strengthened by the pandemic. In 2019, nearly two thirds of businesses had adopted some form of flexible-work policy. Now cities such as London, Paris and New York are exploring new ways of urban living, as thousands of businesses consider downsizing their space. Conversion of office space into residential hubs will follow, with these spaces supporting wider community activities. The Paris administrative region has already committed to turning one third of its underutilised office space into residential housing.

It is not just offices that will become connected, mixed-use communities. Even before the pandemic, many UK property developers were looking to convert retail outlets into housing in response to the changing high street. John Lewis and IKEA are both seeking to retrofit retail space into a mix of private, affordable and social housing. This aligns with a 2020 report by the Social Market Foundation, a public-policy think-tank, which argues that the UK government should look to turn empty shopping parades into residential hubs. It concludes that replacing this commercial space with residential property could create 800,000 additional homes. In 2021, office parks and shopping arcades will become residential hubs with local work, retail, care and leisure spaces.

This will be facilitated by the continued rebalancing of individual and communal needs, leading to a growth in intergenerational, socially integrated communities. Independent living in western societies is an accepted sign of adulthood, but co-living still enables this. We will see the construction of new-style family homes which incorporate an adjacent unit for ageing parents. This will then become the first home for the adult children, until they then move into the family home and the parents become the residents of the adjacent unit, all maintaining a degree of independence.

Sarah Harper is Clore prof. of gerontology at the University of Oxford

Intergenerational living can also occur among unrelated people, leading independent lives. London-based startup The Collective and PLP Architecture are developing ways of living based on individual space and shared experiences, such as their Old Oak co-living space in west London, which is aimed at young, city-based professionals. The collaboration is considering such collectives for all ages.

The extension of intergenerational shared sites is starting to take shape around the UK. Take Marmalade Lane in Cambridge, a cohousing development of families, young workers and older adults, who jointly manage their living environment. Or Granby Four Streets in Liverpool, which is being retrofitted through community land ownership to turn empty buildings into affordable homes, creating accessible shared public space. This trend will continue well into 2021 and beyond.

In the rental sector too, forward-thinking landlords are moving towards occupancy from cradle to grave, with one third of investors and operators of privately rented housing considering this to maintain buoyancy in the rental market.

This development of collective living is not just about "hardscaping" the physical environment. It is also about "softscaping" our neighbourhoods. The Danish concept of "dense low" architecture, in which buildings are kept low and tightly packed to promote social contact, has led to the concept of the "soft city", with its blurring of indoor and outdoor space, enabling the sharing of external private spaces with public common space. The Donnybrook Quarter social-housing project in east London is an example of low-rise, high-density housing that is also low cost and high quality. Two new streets have created a rejuvenated public space where one street widens to become a public square, enhancing walkability and community interaction. A similar philosophy is behind the retrofitting of Dronningensgade Street in Copenhagen's Christianshavn district. Located next to a public square, close to the main thoroughfare, various non-residential uses have flourished on the ground floor – shops, offices, a restaurant and music venue – alongside a range of dwelling types, including a student residence. The courtyard includes a nursery and a shared laundry.

The soft-scaped intergenerational community of 2021 is a policy solution to tackle concentrations of deprivation and poverty. Refitted and refurbished residential, corporate and retail spaces will enable professional, managerial and service workers of all ages to live alongside each other in the new hub of work, care and family – the home.

States set the voting stakes

There will be a wave of redistricting around the United States as information from the 2020 Census rolls in – various bodies in all 50 states will redraw the legislative districts. Re-apportionment, as it's formally called, has happened every decade since 1929 and both parties are targeting 12 states in particular.

We will learn important lessons about openness from the global response to the pandemic

International co-operation will promote collective social action over bolstering the profits of businesses

By **Kimberly Clausing**

Kimberly Clausing is a professor of economics at Reed College in Portland, and author of *Open: The Progressive Case for Free Trade, Immigration, and Global Capital*

THE US PRESIDENTIAL ELECTION WILL OCCUR JUST after The WIRED World goes to press. Here, I assume that Donald Trump will lose. If that assumption proves incorrect, the following will remain an aspiration...

Looking ahead to 2021, the bad news is that the pandemic's effects will linger, casting a pall over world economic growth, limiting the mobility of people, and causing untold human suffering. The good news is that the pandemic itself will have demonstrated the value of openness and collaboration, and political change in the US will put an end to a particularly poisonous form of economic nationalism.

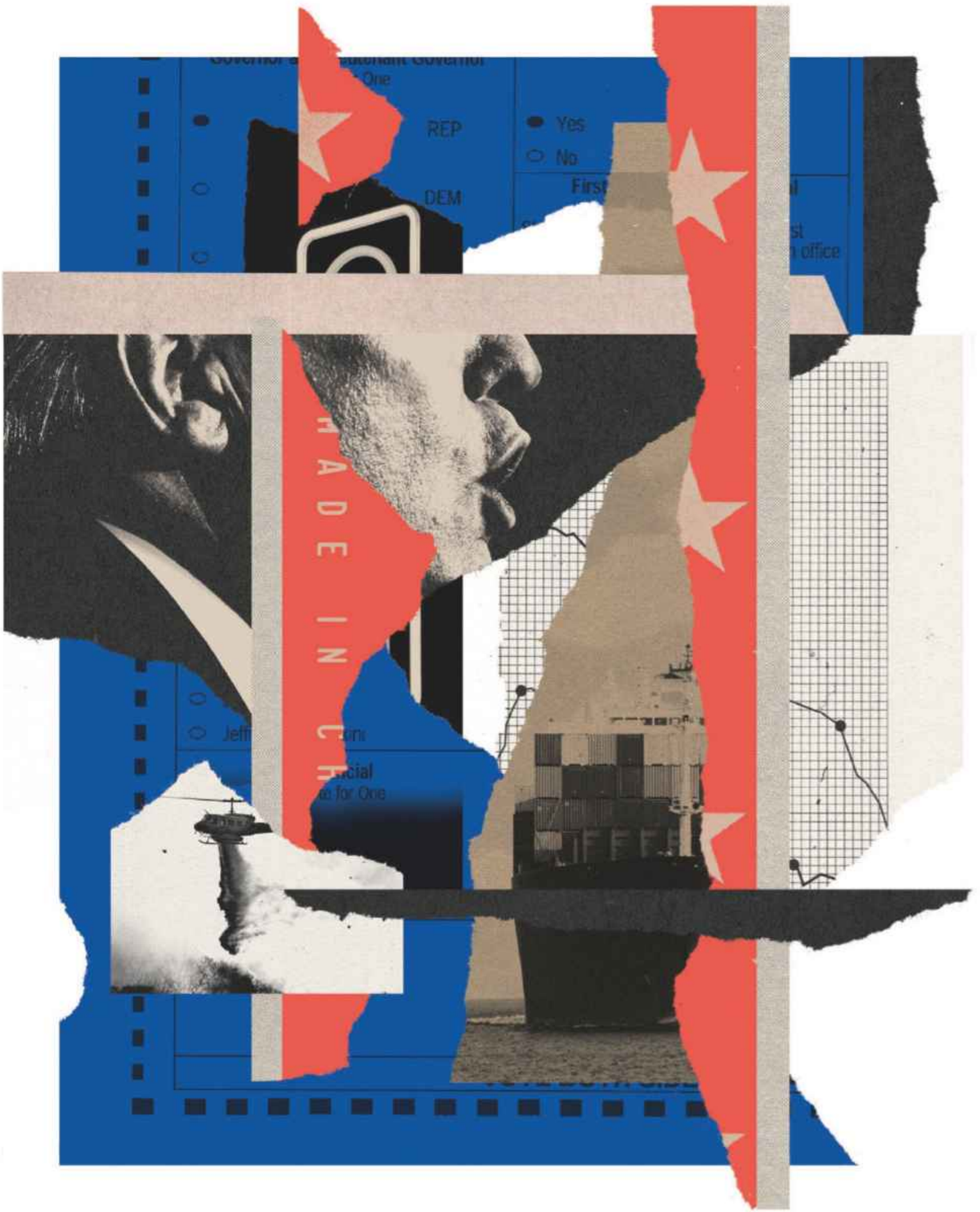
The countries that have best survived the onslaught of the coronavirus have demonstrated the value of science, the importance of swiftly learning from the experiences of other countries and the precious benefits of competent, organised public administration. In the meantime, the spectacular failure of the US to combat the virus has given us such a vivid demonstration of incompetence, ignorance and isolationism that the American voters have learned their lesson.

The "America first" doctrine will therefore justly collapse under the enormous weight of its many obvious policy failures. Sabre-rattling with China has neither improved the wellbeing of US workers nor of the Uighur population in China. On the contrary, US workers have faced higher prices at the store, farmers were unable to sell their crops due to export retaliation, myriad industries faced uncertainty and disruption, and the Chinese government has had a convenient outsider to blame. Trade disputes and retaliation have gone far beyond China to reach Canada, the European Union, India and Mexico. These trade tantrums merely made international policy problems more difficult to solve. Trump's immigration policies were even more disastrous, to both the deeply unfortunate targets of the restrictions, as well as the image of the US around the world.

Such policy failures will be soundly rejected in 2021, and in its place will be an attempt to refashion globalisation in a more inclusive form. International agreements will no longer be centred around the needs of business on intellectual property or investor-state disputes, and will instead focus on global collective-action problems. Toward that end, the OECD and G20 will continue their push to tackle tax competition and corporate profit shifting, and the US will become a willing partner in these endeavours.

The global coronavirus pandemic will remind nations that humanity's problems are, more often held in common, and the issue of climate change will again be addressed more seriously. The United States will rejoin the Paris agreement (assuming withdrawal is completed on schedule, one day after Trump's defeat). The lingering shadow of coronavirus will help polities throughout the world see the value of greater investments to solve these collective-action challenges.

Both in 2021 and beyond, the success of globalisation will depend on how economic policy responds to its downsides. We will see that the massive disruption caused by technological change, international markets and capitalism are best paired with a tax system that asks for fair contributions from the winners of the global economy. This is in order to help those less fortunate and to finance important public investments in infrastructure, education, healthcare, research and building a sustainable future. In 2021, when complemented with adequate domestic policies, we will see that globalisation can – and should – be an essential force for good for a long time to come.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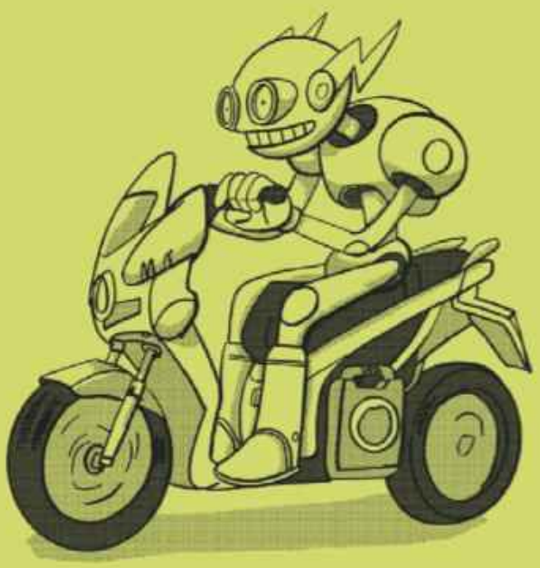


Gear

ILLUSTRATION
THOMAS JENNINGS

Power moves

By **Jeremy White**

Despite Covid-19's disruption to the automotive industry, Deloitte has adjusted its forecasts for the global electric vehicle (EV) market upwards to 31.1 million units sold annually by 2030. And, as we become used to electric cars, it's paving the way for other forms of EV transport, including commercial drones, configurable buses and even eVTOL (Vertical Takeoff and Landing) craft. Here's our pick of what you'll see on roads, waves and in the sky in 2021.

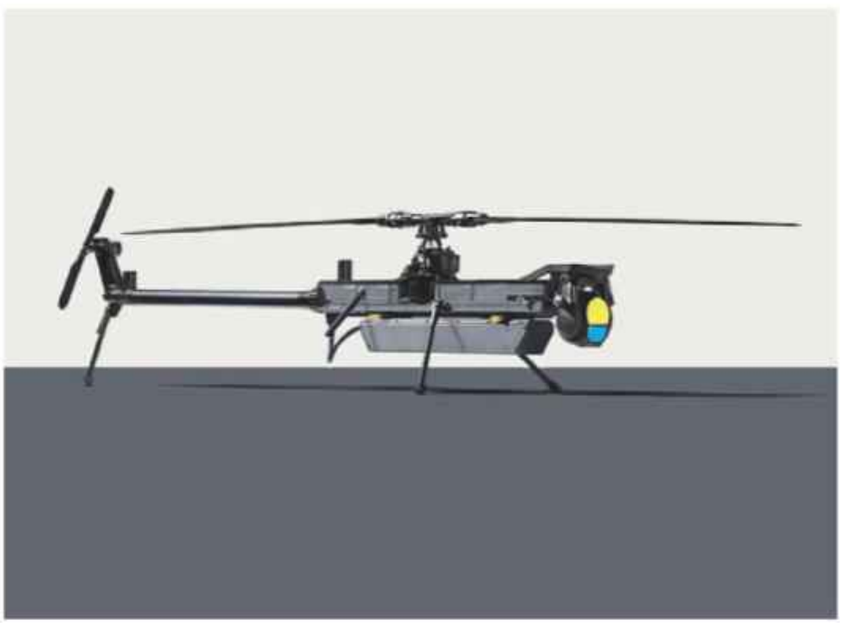
1. Volocopter VoloCity
With a calculated range of 35km and an airspeed of 110kph, the VoloCity is designed as an on-demand inner-city air taxi. It keeps the prototype version's 18 rotors powered by nine lithium-ion battery packs, but has improved on the passengers-only offering with a maximum payload of 200kg – good enough for you and some luggage. *volocopter.com*

2. Canyon Precede:ON CF9
Covid's chilling effect on taking public transport means 2021 will be the year of the e-bike. Canyon's luxury Precede:ON sets itself apart from the pack with a pedal-assist that's controlled by cadence (the speed you're pedalling) – rather than a basic pre-set "power mode". Just input how fast you'd like to spin, then set off. *£4,699 canyon.com*

3. Bell APT 20 multicopter
Bell's new APT delivery drone (Autonomous Pod Transport) combines a vertical takeoff with the ability to switch to horizontal winged flight for increased speed and range. The 0.9m x 1.5m APT 20 can carry a payload of up to 32kg over 55km, or about 28km if you want the drone to turn around and make it home without stopping to recharge. *bellflight.com*

4. eBussy
This modular light EV with solar panels and recuperating drives can be configured into more than ten different versions, from a pick-up to a campervan. The company claims a daily range of up to 200km, and a maximum range (if you add the larger 30kWh battery option and solar modules) in excess of 600km. *From €19,600 electricbrands.de*

5. Audi e-tron GT
This all-wheel drive, full-electric e-tron GT was developed with Porsche. Capable of charging at 350kW, it can top up to 80 per cent in under 20 minutes, giving you 434kW (590hp), 0 to 100kph in 3.5 seconds and a top speed of 240kph. And if plugs ruin your 2021 aesthetic, it can also get its juice via an optional wireless induction plate. *audi.com*



6. Anduril Ghost 4 tactical drone
After Palmer Luckey sold Oculus to Facebook, he founded military-tech firm Anduril. The Ghost 4, which ships to the military in 2021, is an autonomous, near-silent VTOL drone with an AI that performs 32 trillion operations per second. It can be carried in a rucksack, assembled in a flash, and its mission modules can be field-swapped in moments. *anduril.com*

7. Super Air Nautique GS22E 2021
Nautique has partnered with sister company Ingenity Electric to make the GS22E towboat the Tesla of the wakeboarding world, with a battery system that is good for two to three hours of watersports. The Surf System integrated into the hull on either side of the transom shapes the water and creates perfect waves behind the boat. *nautique.com*

8. Seat MÓ eScooter 125
Small, lightweight and ideally suited to urban driving, scooters will lead the way for EVs in 2021. Seat's upcoming MÓ uses a zippy 9kW (about 12hp) motor to deliver 50kph in less than four seconds, and a top speed of 95kph. The 5.6kWh lithium-ion battery is swappable if you don't have time to top up, and it can even charge other devices via USB. *seat.com*

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08

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Finance will look forward, not back

The aftermath of Covid-19 will lead to a fundamental shift in the way banks lend to businesses

By **Rishi Khosla**

THE RISK MODELS THAT BANKS USE TO help inform their commercial-lending decisions have been dealt a blow by Covid-19. The pandemic has presented a crisis where historical correlations do not hold. In 2021 we will find new ways of assessing risk that use forward-looking as well as backward-looking data. This will make lending smarter and better for everyone.

Traditional risk models are based on historical data, but the dynamics of the Covid-19 crisis mean that extrapolating from the past may now be a less helpful approach. As is the case with trade wars, natural disasters or, indeed, climate change, pandemics are by their very nature situations that are hard to predict or plan for. We can make assumptions based on what we have seen with similar events in the past, but no two are the same, so any view of them needs to be supplemented with forward-looking data, which takes into account future challenges that may arise.

In the context of commercial lending, forward-looking data, such as projections of revenues, provide an additional means of understanding future risks. As these offer a glimpse of a possible outcome under certain assumptions, they can never be as accurate as historical numbers, but they do give banks and borrowers the opportunity to act with foresight. In a fast-changing world, a timely change of course based on imperfect data could be better than 20/20 hindsight when it's too late to avoid a problem.

Risk models are also less useful when a situation is changing as rapidly as it is now due to the pandemic. Take, as an example, two contrasting restaurants. Under lockdown, a fine-dining restaurant is unlikely to experience any business, whereas a pizza delivery chain may see an increase in trade as people stay at home. When lockdown eases, however, and restaurants are allowed to reopen (but with strict social-distancing and cleaning measures in place), the situation then is quite different. The formerly empty fine-dining restaurant, which had always spaced customers far apart with a lengthier turnaround service, is now experiencing a surge in reservations as many diners look to make their first meal out in months "special". Meanwhile, the pizza chain may see demand for deliveries shrink slightly as people rush to enjoy the outdoors and take advantage of their freedom. This is also in a context where we are seeing unprecedented government support of the economy. A situation like this is so dynamic and ever-evolving that banks need to be able to rerun scenarios on loans on a regular basis, using new, real-time data as they receive it.

Lending models will also need to provide an understanding of the portfolio at the granular-loan level, taking into account the individuality of each business and how metrics such as their cashflow may be affected by the crisis. A luxury boutique that specialises in made-to-measure gowns is likely to see its revenues obliterated as few customers would have an occasion to wear one of its creations. E-commerce businesses that specialise in yoga wear, by contrast, may see a substantial increase as customers practise more yoga at home and order more online. As the consultancy McKinsey has noted in its report on lending after Covid-19, "to evaluate creditworthiness properly... banks must go beyond analyses of sectors or subsectors and assess individual borrowers."

As a result of this crisis, banks are having to change the way they lend to businesses. They will need to use forward-looking as well as backward-looking data, rerun analysis on an ongoing basis, rather than annually, and take a granular, loan-by-loan approach. The best banks will expand on these practices that have emerged because of Covid-19 in 2021 and beyond.

Rishi Khosla is co-founder and group CEO of OakNorth

PIZZA

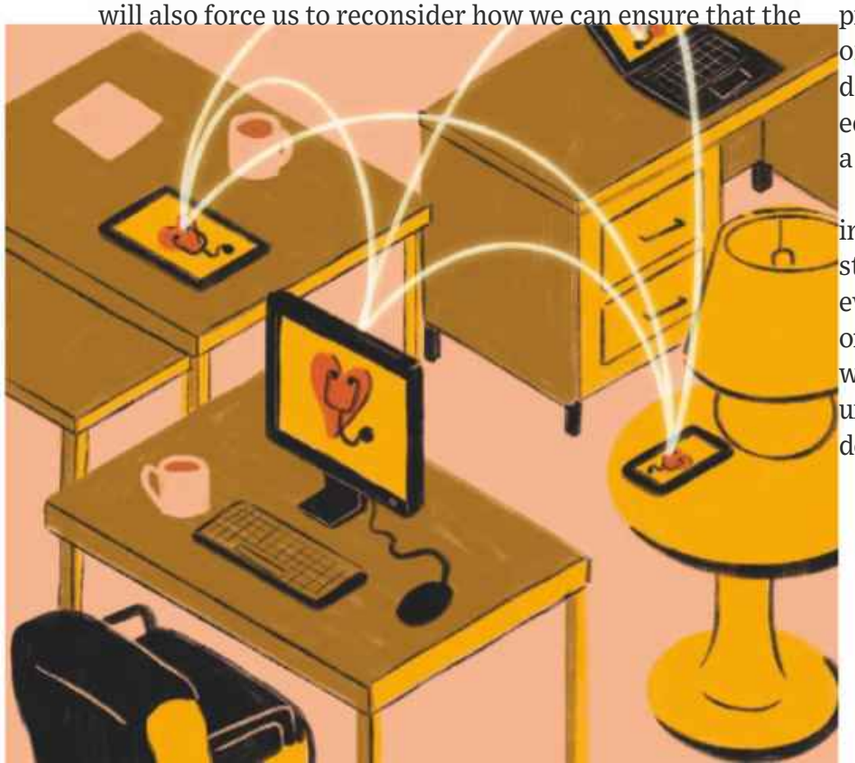
A virtual-first world will be all-inclusive

Purpose-driven digital strategies will ensure no one gets left behind in 2021

By **Jacky Wright**

THE MOST SUCCESSFUL COMPANIES IN 2021 will be those that adopt and put into practice a purpose-driven digital strategy for a new "virtual-first" world. This will focus on the societal problems that are a core tenet of a company's approach, in an increasingly online world.

The impact of Covid-19 on our society – economically, politically and socially – will mean re-examining the role of a digital-transformation strategy. We will need to review how we work, how we engage with customers, and how we develop and run our operations in a virtual-first world at pace. This will raise questions about how we should evaluate our need for physical space against operating a truly virtual service. It will also force us to reconsider how we can ensure that the workforce of tomorrow is effectively skilled and reskilled. Organisations will need to lead on bridging the digital divide and providing access for all, so everyone can participate.



Accelerated innovation and transformation to meet the needs of Covid-19 over the past year have redefined business operations across all industries and given them a much more digital focus. In healthcare, for example, the shift to telehealth has resulted in 93 per cent of primary-care visits delivered virtually in England alone. Aside from unlocking new business models, telehealth has tremendous potential to address health disparities in rural and underserved communities by promoting preventive medicine and reducing the reliance on emergency and urgent care. Telehealth delivered in this way, and balanced with equitable broadband access, is the essence of a purpose-driven digital strategy.

Every business model and technology innovation will be built on a ubiquitous-data strategy, where information anywhere and everywhere is the standard. The proliferation of connected devices and cloud-based services will allow organisations to capture and harness unprecedented amounts of data. This will drive decisions across their operations, deepen their

Jacky Wright is chief digital officer of Microsoft. She is writing here in her personal capacity

understanding of customers and help them develop new products and services. Governments will increase their engagement and role in defining and governing data proliferation, security and privacy for businesses and citizens. As more citizens demand greater control over their own data, corporate policies around transparency in how that data is collected and used will become significantly more important. A prime example is the ability of governments to understand and share results of clinical trials globally, and accelerate solutions in the face of health crises.

We will also have the opportunity to lay a digital foundation that will increase equitable inclusion across the globe. Local technology innovation will hasten economic recovery, growth and trade ability in this virtual-first world. It will enable communities to solve problems locally and apply them globally. Technology advances and innovation will focus on AI-enabled, connected customer experiences in two realms: interconnected platforms as the transport mechanism; and edge computing and devices as the consume-and-capture service. This will rely on providing wireless-network technology in rural and underserved communities, and offer services where previously excluded. Assisted technology, with a focus on accessibility for all, will be a core customer-experience strategy.

As we continue to address crises, we will have to begin solving today's problems with a view to the challenges of the future. A big question for 2021 will be how we define our moral compass as a society. The impact of the pandemic on global agriculture – significant disruptions in labour availability, in the supply-chain ecosystem and increases in consumer demand – has highlighted the vulnerability of our connected world. In 2020 we will have to harness technological innovations and new business models in precision agriculture to address this particular example. The challenge will be to do this in more sustainable and equitable ways.

As we reimagine a virtual-first future and its impact on healthcare, education, environment, infrastructure, policy and commerce, the organisations that harness ingenuity and agility – and anticipate the future from a moral perspective – will be best positioned for success in 2021 and beyond.

Cryptocurrency for crypto-taxes
Zug, a Swiss canton, will begin accepting tax payments made using cryptocurrency from 2021. Other cantons in Switzerland already provide this facility – such as the financial hub of Geneva. Zug will accept taxes of up to 100,000 Swiss francs (£84,125) paid in Bitcoin or Ether from February 2021.

Recruitment will no longer be tied to your location

Forget geography: skillset, personality and flexibility will be the key drivers for hiring

By **Tania Boler**

THE COVID-19 PANDEMIC HAS SHOWN US THAT we don't have to be in the same place to get work done. Tech giants such as Microsoft have already announced that they will keep many of their teams working from home into 2021. Mark Zuckerberg has said that Facebook could see at least 50 per cent of its employees working from home in the next five to ten years. In 2021, we'll see companies of every size offer remote working by default.

In part this will be a cost-saving measure, but it will also change how technology companies find and hold on to talent. Technology isn't confined by borders, but until now, the way these businesses have recruited has been. In 2021, we will see HR teams changing their recruitment criteria, as firms realise proximity to a set office location can no longer be a key driver in the hiring process. Where someone lives will take a backseat to their skillset, mindset and personality – traits which will far better serve technology businesses than the ability to show up to the office every day.

Remote working will put a renewed hiring emphasis on autonomy, with organisations looking for employees who can work without constant supervision. And employees, in turn, will expect autonomy. No one wants to spend five hours a day on a Zoom call discussing what they have to do, and then try to do that work in the remaining hours of the day.

We will also see these changes extending beyond traditional office settings. The way

products are designed, for example, will also be modified if designers are unable to meet in person and tinker with physical prototypes to understand how they feel.

Instead, product-design teams will be forced to find new ways of collaborating, regardless of distance and location. Some designers are already strapping GoPros to their heads so they can talk through a prototype remotely. But this can't recreate that all-important moment of touching and feeling something for yourself.

In 2021, we will see companies experimenting with augmented-reality tools and virtual-reality headsets to create environments where teams can manipulate products for themselves, even though they might never see that prototype in the flesh.

And product teams will also benefit from this new borderless world. By having them spread over a range of countries and locales, companies can ensure their technology truly meets a global set of expectations and needs, rather than being narrowly focused on wherever their offices are located.

It's taken some time, but 2021 promises to be the year the technology industry finally moves beyond the limits of the physical office, tearing down outdated barriers to recruitment based on borders and increasing the diversity and skillsets of their teams. This will be a change driven by necessity, but it is one we will all benefit from for years to come.

Tania Boler is founder and CEO of Elvie

Algorithms will make remote working more serendipitous

AIs will matchmake for creativity and digital watercooler moments

By **Carl Benedikt Frey**

DESPITE PREDICTIONS OF THE DEATH OF the office in the 1990s, remote working has been slow to take off. Across the EU the share of the population working from home has hovered between four and five per cent for the past two decades.

However, Covid-19 looks likely to change all of that. In 2015, researchers at Stanford University found that remote work increased performance by 13 per cent due to fewer breaks, sick-days and a quieter working environment. And several anecdotal studies of remote working during the pandemic show that people working from home have become more productive.

In 2021, however, we will have to grapple with its downsides. While working from home brings efficiency gains in the short run, the danger is that it will imperil the innovation that drives business performance over the long run. Indeed, efficiency is the enemy of innovation, which is fundamentally about exploration. Having everyone working by themselves makes it hard for people to interact and explore new possibilities.

The solution to this dilemma will come from artificial intelligence (AI). The inherent trade-off between exploration and efficiency is well known to AI researchers. One question that those working in AI often have to grapple with is how often an algorithm should take actions that it hasn't tried, as against actions it has already tried that will usually lead to some reward.

Untried actions can yield spectacular results. For example, when the DeepMind computer program AlphaGo beat *Go* world champion Lee Sedol in 2016,

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it did so by exploring moves most human players had never seen before. Prior to move 37 in the second match against Sedol, AlphaGo had calculated that there was a one-in-ten-thousand chance that a human player would make that same move. And the adventurous gamble paid off.

Human innovation involves a similar process of exploration and, to facilitate innovation, companies must get their employees to "collide". Before the pandemic, this was achieved through open-plan architecture that encouraged "water-cooler" moments of unplanned encounters. But, with many employees working from home, corporations will have to find different ways to facilitate these kinds of random interactions.

The prime reason why, until now, people prefer to work together in person rather than online is that digital technologies have provided poor substitutes for the sporadic encounters that happen at work. But AI has the potential to change that. AI is already good at matching, whether it is finding the right film on Netflix or the right partner on a dating app.

In 2021, companies will be throwing resources at developing this kind of matching AI in the workplace. Based on employees' emails, Google searches and other data, AI algorithms will be able to deduce what people are working on and their current interests and will act upon that by making digital introductions that would otherwise not have happened. Employees will then evaluate the usefulness of each digital encounter, providing feedback for the AI to learn from.

As more companies grapple with the problem of powering innovation at a time when many are forced to work from home, we will see more AI applications being developed to promote sporadic digital encounters in 2021. If we can get this right, as the economist Frances Cairncross observed back in the 1990s, the world in which millions of people trooped from their home to the office each morning, and reversed the procedure each evening, may finally strike us as bizarre.

Ecological investments
The European Investment Bank (EIB) will have phased out funding of all coal, oil and gas projects by the end of 2021. Since 2013, the EIB has funded 13.4 billion euros (£12.2 billion) of fossil-fuel projects, but it plans on becoming the world's first "climate bank" in 2021, a year later than originally proposed.

Diversity will be taken seriously

Organisations will commit to undertaking real changes in the way they tackle racial injustice and workplace equality

By **Chi-chi Nwanoku**

IN 2021, ORGANISATIONS OF ALL KINDS will realise that they have to make racial justice a core part of their mission, not just an add-on. Prompted by the Black Lives Matter movement, many organisations made gestures in this direction – publishing slogans on Instagram, asking Black people and minorities what they could do to fix these problems and so on. But gestures don't always lead to change.

In 2017, a report by McKinsey found that in the US, companies were spending more than $8 billion a year on unconscious-bias training. A meta analysis of decades of research conducted in 2018 by Frank Dobbin, professor of sociology at Harvard, and Alexandra Kalev, associate professor of sociology and anthropology at Tel Aviv University, found that even firms that engaged with diversity training did not necessarily hire more diverse managers. (Some became less diverse.)

Instead, in 2021, organisations will have to ask themselves some awkward questions. Why, for example, have they gone decades without hiring a Black person, particularly if they're based in a diverse city? Do they actively look for and recruit people of colour? What is the experience of people of colour in their organisation? Companies will also have to make significant changes to demonstrate their commitment to diversity, which will include people in power stepping aside to make space for more minority representation. In June 2020, Alexis Ohanian, co-founder of Reddit, resigned from his company's board and called for his position to be taken by a Black candidate. (Y Combinator CEO Michael Seibel took his place.) 2021 will need more reshuffling of this kind at the top tiers of firms.

Five years ago I started the Chineke! Foundation – the Chineke! Orchestra and the Chineke! Junior Orchestra – the world's first majority Black, Asian and ethnically diverse orchestras. Many organisations and individuals felt threatened by what we represented and how we made it obvious that the arts had a long way to go when it came to representation and equality. We were all highly trained classical musicians who'd had to swim upstream to get to where we were. Today though, we are now a core part of the UK's arts world, an associate orchestra of London's Southbank Centre, and we have played at the BBC Proms.

I am a musician and when I look at the difference between diversity training and actual change, I often think in terms of learning music. If I have to learn a challenging new piece, it doesn't matter whether the best teacher in the world is teaching me which bowing or fingering to use; if I'm not putting in the work myself, any progress won't stay with me for a long time. Organisations must do the same in order to enact real change, rather than pay lip service to diversity. In 2021, they will realise that tackling racial injustice is a real-world, long-term project where actions speak louder than words.

Chi-chi Nwanoku is founder of the Chineke! Foundation

We will pay to be free from adverts

In a reversal of the online ecosystem, the next wave of startups will be customer-first and paid for

By **Sridhar Ramaswamy**

2021 WILL SEE THE END OF THE ONLINE WORLD'S LOVE affair with "free" online services. As we now understand, providing "free" content and services means relying on advertising income to make money. Those ads started innocuously, but they have now become unwelcome and unwieldy, and many are designed to closely relate to content, leading to a confusion between editorial and marketing. In addition, they have led to a world where companies track everything a consumer does online to serve them even more ads.

In 2021, we will see the rise of a new class of services that are paid for and ad free, and thus have no incentive to track an individual's every move across the internet. Companies will build products that are founded on a simple business model and focused on just the customer. The customer, meanwhile, will pay a fee, but will realise they are getting value for money.

Entertainment providers such as Netflix, Spotify and HBO have always been paid for, but now we are seeing other providers adopt this model. There has been a rise of newsletters and online publishing platforms, such as Scroll, that deliver high-quality, ad-free, paid-for content. In the productivity sector, companies such as Superhuman and Hey, which market email applications, are taking this approach. My own company Neeva will also charge a subscription to provide search that is ad free and private.

There are two significant advantages to the paid-service model. Companies that adopt it will have a single focus, the customer, rather than having to satisfy advertisers too, and they will be able to innovate and use scale to serve them better. Moving away from "free" will also help the online world satisfy understandable regulatory concerns about data privacy. If there are no advertisers to share customer data with, that data will remain safe.

There's no doubt that the idea of "free" helped kickstart the vibrant online ecosystem we have today, and while there will always continue to be a market for "free" services, 2021 will mark a turning point that will give rise to the paid-service model. When I was at Google, I saw how the never-ending temptation to adopt a slightly more aggressive approach to adverts ultimately led to a poorer experience for the consumer. In 2021, we will see the internet grow up into a world where consumers are happy to pay for quality products and services, and the grip of advertisers over our online life is weakened.

Sridhar Ramaswamy is CEO of Neeva, and a Venture Partner at Greylock Partners. He was previously the SVP of Google Ads

Nationalism will lead to lower-quality medicines

Taking back pharmaceutical production from China will impact western healthcare

By **Elizabeth Pisani**

COVID-19 HAS FORCED POLITICIANS TO confront something they have up till now preferred to ignore: the fact that most rich countries have effectively outsourced large parts of their medicine production to a handful of other countries – notably China and India. This is especially true for the active pharmaceutical ingredients (APIs) that are the building blocks of pills and injections.

The global medicine market is shaped like an inverted pyramid. Its base comprises APIs, made mostly in China. Many countries manufacture antibiotics, for example, but in 2018, the latest figures available, China was the origin of 82 per cent of all antibiotic ingredients used worldwide. And above that lies a layer of cheap generic medicines, a very high proportion of which are produced in India.

In 2021, calls to bring API production home, in the name of pharmaceutical security, will intensify, led by politicians in both rich and middle-income countries who lost credibility and millions of dollars panic-buying substandard personal protective equipment and medicines to deal with Covid-19.

It's hard to predict how much of this production will actually be clawed back, especially to rich countries, as the move will be resisted by at least two powerful lobbies. The first are environmentalists, who will oppose API manufacture on their home turf. Making APIs is often a messy business, particularly at scale. Some pollutants from the process can threaten waterways and wildlife; others, such as waste antimicrobials, contribute to the spread of drug-resistant infections in humans and animals.

The second source of resistance will be the pharmaceutical industry itself. API production is a high-volume, low-margin business, which requires massive capital investment. Big "innovator" pharma has little interest in making these investments, hence the outsourcing of manufacture of APIs.

To the extent that onshoring does happen, it will have two effects. Firstly, since all competitors have a hard time matching China on price at any given level of quality, domesticating the production of medical ingredients will push up medicine prices across the board. Low-cost, high-volume generic medicines, many of them targeted at widespread chronic conditions such as heart disease, diabetes and psychiatric disorders, and which make up the core stock for many a national health system's pharmacies, will be affected most, as active ingredients account for up to 90 per cent of their production costs.

The second effect will be an erosion of medicine quality, especially in lower- and middle-income countries where health budgets are already vastly inadequate. The need to scale up affordable healthcare while keeping medicine prices low will lead to producers cutting costs wherever they can. As long as national medicine regulators keep a watchful eye on what is happening in their countries, cost-cutting should not erode the quality of medicines. But the Covid-19 pandemic has taught us that some national medicine regulators are easily bulldozed by politicians whose agenda is shaped by opinion polls rather than patient safety. If we are not careful, in many countries in 2021, we will see more domestically produced medicines – but they won't necessarily work.

Elizabeth Pisani is a visiting senior research fellow at the Policy Institute, King's College London

Net zero is the No.1 goal

Decarbonising the economy will become a key mission statement for many new startups in 2021

By **Azeem Azhar**

ENTREPRENEURS WILL FLOCK TO TACKLE the challenge of decarbonising our economies and industries in 2021. The global economy emits 38 billion tonnes of CO_2 into the atmosphere each year. Other greenhouse gases, such as methane and nitrogen oxides, add the equivalent of 12 billion tonnes of CO_2 to this figure. Decades of work and trillions of dollars of investment in fossil-fuel-driven industries have deep roots in our societies. Achieving "net zero", as the elimination of carbon emissions is known, is a lofty goal.

This drive towards net zero has attracted few entrepreneurs and is a tough sector for investors. In the first decade of the century, clean tech was heralded as the next boom area. Between 2006 and 2011, $25 billion flowed into the sector. Half was lost.

Now, however, consumers are more aware of the importance of tackling climate change and are putting pressure on companies to adapt. More than 200 organisations, including Apple, Amazon and Microsoft, have committed to net zero. Microsoft has set itself the goal of being carbon negative by 2030, meaning that the firm will eliminate carbon emissions generated by its own business operations, including its suppliers. IKEA has gone further. By 2030, the company wants to be carbon negative not only in its own operations and the activities of its suppliers, but also regarding the emissions generated by the use of its products in the hands of customers. This has created a huge opportunity for entrepreneurs. Each of those firms will need innovations that don't currently exist.

Some enterprises are already paving the way. Elon Musk has probably done more than anyone to put the car industry on the path to net zero. Energy Vault, founded by serial entrepreneur Bill Gross, is developing electrical-energy storage blocks based on the interchange of potential and kinetic energy. Jennifer Holmgren's company LanzaTech, based in Illinois, is finding ways to recycle carbon emissions into biofuels and agricultural feed. 80 Acres Farms, based in Cincinnati and founded by Mike Zelkind, is pioneering high-intensity urban farms that have a lower environmental footprint than traditional agriculture. In 2021, they will be joined by more entrepreneurs who will provide the means for us to move towards a net-zero economy. These will include San Francisco-based Wren, which is developing ways to make it easier for consumers to offset their carbon emissions, and Singapore's Equilibrium World, which is helping companies to track and manage their environmental footprint.

Innovations like these will also attract capital. According to PwC, in 2013, only $418 million of venture capital flowed to startups tackling decarbonisation. By 2019, that number had risen to $16 billion, an annual increase of 84 per cent. Technology investors such as Sequoia Capital and USV have announced a new focus on climate investing. London's Kindred Capital, where I am an advisor, is seeing a much greater flow of founders addressing the carbon problem. They are joined by new dedicated venture funds focusing on climate change, such as Chris Sacca's LowerCarbon and Europe's Pale Blue Dot.

However, entrepreneurs and investors will not be able to change the world's economy by themselves. In 2021, we will understand that replacing incumbent systems with cleantech will require the co-operation of large companies and governments, too. In 2020, Amazon announced a $2bn Climate Pledge fund. We can expect more capital, from dedicated investment funds to corporates making commitments, to follow suit. Only by global co-operation will we see our way to a net-zero future.

Azeem Azhar is the author of *Exponential*, and the founder of Exponential View

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JANUARY

Digital offices will face social media–style toxicity

Without guidelines, the tools used for remote working risk enabling bullying and discrimination

By **Ellen Pao**

SEXUAL AND RACIAL HARASSMENT WILL MOVE into digital workspaces during 2021, with work platforms destined to go the way of social media. Companies will have to introduce guidelines for online behaviour.

Working from home has blurred the line between professional and personal behaviour. There have been examples in which some employees have made offensive comments in their conversations with colleagues – and companies are finding these interactions hard to police. Combined with the stress caused by lockdown, this inaction means conflicts escalate and employees feel increasingly isolated.

Discrimination by race and gender is a long-standing business problem, and my organisation, Project Include, has found that it has become a bigger issue in a number of online workplaces. In 2021, companies must provide training and guidelines for employees on what is appropriate behaviour, and what isn't, when working on remote teams.

Exclusion of under-represented groups is already a problem in offices, but it is even easier to have side conversations in tools such as Slack, direct-messaging or chat functions. When communication is online, colleagues can't tell that they're being excluded, so they don't know to ask to join and no one feels compelled to invite them. Tools make these online groups permanent and amplify the feeling and reality that many employees are "out of the flow" of the office.

The danger is that this exclusion will increase. People will become less aware of what is going on, less involved in decision-making, and encounter fewer opportunities for promotions and raises. People who are struggling will get lost, because no one will see that they need help. As we've seen in social-media platforms, lack of enforcement will cause negative interactions to continue, spread to other employees, ramp up in volume and increase in vitriol.

Companies with poor management skills will try surveillance methods, but as managers track employee time online and check in on them more frequently, many employees will feel uncomfortable, untrusted and unhappy. They will find ways to game the system, wasting everyone's time and money. Companies will need to build trust in their teams and demonstrate that their wellbeing is important by treating them as adult enough to work remotely without constant oversight. The guidelines will have to reflect this atmosphere of trust and make a company's commitment to it a reality. If not, HR teams will be dealing with multiple screenshots of inappropriate comments, offensive jokes and memes, illegal messages and ongoing exclusion – resulting in reduced output, poorer decisions and lower team and company performance.

HR teams will be dealing with screenshots of inappropriate comments, offensive memes and illegal messages

Without guidelines, we will see non-core communication channels solidifying around political identities, and employees causing harm to co-workers who already feel isolated in companies that, despite their statements in support of movements such as Black Lives Matter and #MeToo, have done too little work to improve internal cultures. In 2021, all companies will have to change the way their teams communicate and collaborate remotely to ensure they don't just become another channel for the nastiness and harassment that is plaguing social media.

Ellen Pao is an investor and the CEO of Project Include

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Virtual worlds – our third place in 2021

Digital meeting spaces will enable shared experiences and new communities

By **Herman Narula**

ONLINE WILL BECOME THE "THIRD PLACE" where we do much of our socialising in 2021. As the Covid-19 pandemic has disrupted the distinction between the workplace and the home space, we are starting to look beyond video calls and turning to virtual worlds to give us the same experience as our favourite gathering places.

The pandemic saw sharp increases in the numbers of players across many gaming platforms. With schools closed and outdoor opportunities limited, players flocked to Epic Games' *Fortnite*. There are now 350 million registered *Fortnite* players, compared to 250 million in March 2019, helping propel the company to a $17.3 billion (£13.3 billion) valuation. Nintendo's *Animal Crossing: New Horizons*, which offers wholesome co-operation and virtual outdoor adventures, drove Nintendo's operating profits up 428 per cent in the quarter after its release.

In 2021, this online activity will increase and the virtual economy will grow. In some sectors the concept of "going to work" in a virtual space is already gaining ground. Military training in synthetic environments, where realistic exercises and scenarios can be played out in safety, is now widespread. And people are also finding ingenious ways to recreate their real-world, non-work lives online. Couples are conducting weddings in *Animal Crossing* and groups are holding meetings around the digital campfire in *Red Dead Redemption Online*'s Old West.

We've long seen the aspiration of real experiences in virtual worlds. Projects such as Second Life explored the technological and social possibilities for what was then a relatively small online community. Now, a generation that met on Facebook or Tinder is routinely hanging out on Zoom and Houseparty while their children play together in *Minecraft* and *Roblox*. The move to virtual worlds is enabled by increasing data connection, cloud computing and powerful, portable devices – but the cultural shift is no less important.

These inventive applications for game worlds will evolve into other kinds of virtual meeting places. In 2020, game-development students and faculty at the University of Utah built a virtual world where they could conduct their graduation ceremony. The graduating students (or, rather, their avatars) walked in a procession, listened to speakers and received their graduation cords in a recreation of their own campus building. The students built the game in two weeks, using Unreal Engine and SpatialOS, and streamed the ceremony live for friends and family on Twitch.

As events like this grow in number, the online world will provide neutral, easily accessible and playful spaces, which are free from hierarchies. This will be ideal for the sort of shared experiences, adventures and surprise encounters we need to make new connections, create new understandings and drive forward our relationships. This fulfils exactly sociologist Ray Oldenburg's vision that, in order to build society, we need third places where we can "relax in public, where you encounter familiar faces and make new acquaintances".

Beyond 2021, we will be able to begin to weave together thousands of disparate online spaces into single simulations, allowing hundreds of thousands – or millions – of us to gather in the same virtual-world spaces.

Herman Narula is co-founder and CEO of Improbable Worlds

Non-fungible currency hits digital wallets

Unique crypto-tokens will upend online economies by bridging the gap between the virtual and offline worlds

By **John Egan**

LOCKDOWN SIGNIFICANTLY INCREASED the number of hours people spend online. In the UK, the communications regulator Ofcom's annual Online Nation report revealed that, in April 2020, UK adults spent on average four hours online every day, compared with 3.5 hours in September 2019. This has created opportunities for digital-content innovators and, in 2021, they'll have a new way to earn money for their products.

Selling digital assets such as avatar skins isn't new, but there was no way to prevent the replication of those assets by other users. In 2021, we will see a new type of decentralised digital asset called a Non-Fungible Token (NFT). Use cases for NFTs are already being created by decentralised gaming platforms such as Decentraland, Cryptovoxels and Somnium Space.

In economics, non-fungibility means that an item is unique, like an original work of art or a restaurant meal. Fungible items are those that are interchangeable with identical goods – such as gold or tins of beans. NFTs are the product of a technology protocol, published on the Ethereum blockchain in September 2017, that allows for the creation of certifiably singular digital assets. Each NFT is tied to a different identifier, making each token non-fungible and unique to its owner. A developer can create a contract where every token holds a different value, so someone can create a digital asset they can prove is theirs, and sell it for real money.

The case for NFTs has been growing since June 2017, when the launch of CryptoPunks – in which people can buy one of 10,000 unique characters – paved the way for "rare" art on the Ethereum blockchain. In October that year, DADA.Art launched the first marketplace for rare digital art. And In 2018, kitten illustrations on Ethereum-based games such as *CryptoKitties* were selling for up to $160,000. Now the market is expanding, with users gravitating towards complex assets such as tickets to events and even ownership records for physical assets, for example, shares of an artwork or collectible item.

The majority are virtual credits for virtual use, such as a weapon for a game, but the real opportunity for NFTs exists where the virtual worlds and analogue worlds converge. 2021 will see the launch of a spate of mixed-reality hardware products and applications, including the next generation of AR glassware. Mixed-reality NFTs will be at the core of our experiences in this area, from filters, art and game assets, to virtual pets that can interact with the real world, to financial securities and proprietary data streams (such as selling access to your FitBit data). They will allow NFT creators to prosper in a major way.

According to nonfungible.com, which monitors the crypto-collectable market, in July 2020, total NFT sales surpassed $100m. In 2021, that number will be boosted by increased penetration of NFTs into the mainstream. Major brands are already creating and trading NFTs: Nike has used them to create digital shoes that are linked to real-world shoes; Formula 1 has developed a racing and collectables trading game; Louis Vuitton uses NFTs to track the provenance of luxury goods; and Samsung has created an NFT-supported cryptowallet.

In 2021, the Metaverse – a virtual world where people interact with each other through avatars – will see the beginnings of a robust economic system based on the use of NFTs. And that'll make a lot of people very rich.

John Egan is CEO of L'Atelier, a foresight subsidiary of BNP Paribas

The fight for our information ecosystem will ramp up

Deepfakes will be viewed as a very real threat to society and veracity

By **Nina Schick**

AN INCREASINGLY LARGE PROPORTION of video content online will be synthetic in 2021 – meaning wholly or partially generated by AI. Some of it will be benign, and even hilarious, such as the YouTubers who are using the power of AI to deepfake Nicolas Cage into every Hollywood movie ever made – but there will be plenty that have been created with wholly malicious intent. Indeed, the first widespread use of synthetic media – non-consensual deepfake pornography, which almost exclusively targets women – has proliferated wildly since it first emerged at the end of 2017. According to Amsterdam-based cybersecurity startup Sensity, which was founded in 2018 to combat deepfakes in the visual media, the number of deepfake pornography videos online is doubling every six months, and by next summer, there will be 180,000 available to view. By 2022, that number will have reached 720,000.

Nina Schick is a broadcaster and author of *Deep Fakes: The Coming Infocalypse*

In 2021, deepfakes will develop further as weapons of fraud and political propaganda, and we are already seeing examples of this. In early 2020, the Belgian Branch of Extinction Rebellion used AI to generate a fictional speech by Belgian prime minister Sophie Wilmès. To achieve this, the group took an authentic video address made by Wilmès and used machine learning to manipulate the words she spoke to their own ends. The result: Wilmès is generated in a video making a fake speech in which she claims that Covid-19 is directly linked to the "exploitation and destruction by humans of our natural environment".

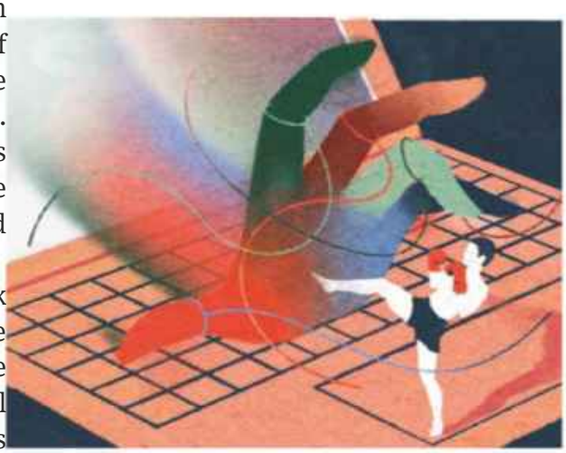
Anyone's identity can be misappropriated in this way. All that's needed are images, video or audio of the intended subject to "train" an AI to produce a convincing deepfake.

A world in which deepfakes flourish will also be one in which doubt can be cast on documented evidence of wrongdoing. If everything can be faked, anything can be denied too. It is difficult to imagine a more serious challenge to the sense of an objective and shared reality that is needed to keep society cohesive.

In 2021 we must begin to fight back against deepfakes by defining the problem as the corrosion of the entire information ecosystem itself. We will continue to use human fact-checkers to validate what is disseminated online, but we will also need technological solutions.

These will broadly fall into two categories: detection and provenance. The US Defense Advanced Research Projects Agency (DARPA) is already developing what it is calling its Media Forensics (MediFor) programme, which uses AI to detect and expose manipulations. Adobe's Content Authenticity Initiative seeks to develop an industry standard for digital-content attribution.

Ultimately, however, our crisis of information will not be for technology to solve alone. Any technological solutions will be useless unless we humans are able to adapt to this new environment where fake media is commonplace. This will require "inoculation" through digital-literacy and awareness training, but it will also require proactive countermeasures, including cogent policy responses from the government, military and civil groups. It is only with the full mobilisation of society that we will be able to build an overarching resilience to withstand the risks presented by our compromised information ecosystem.



We'll wonder how we lived without the Metaverse

A 3D virtual world where millions meet online will become our key social hub

By **David Baszucki**

WE WILL SEE A SHIFT IN THE WAY PEOPLE PLAY, work, learn or simply hang out in 2021. Some of this connection will move into the Metaverse, a digital place where people seamlessly get together and interact in millions of 3D virtual experiences. Early iterations of the Metaverse emerged in the 1980s with VPL Research's DataSuit and Linden Lab's Second Life in 2003. However, it started to feel very real in 2020 as several platforms have been envisioning – and building – their own versions of the Metaverse.

The pandemic, with its requirements of physical distancing, has brought people into online digital environments for a growing range of shared human experiences. Gaming platforms are being used to host meetings ranging from online birthday parties to job interviews. We're already seeing more events with millions of avatars enjoying a collective virtual and social presence in the Metaverse, from concerts to movie premieres. While gaming has initially been the province of such digital co-experiences, it is rapidly expanding. This shift has created urgency for entertainment brands and artists to generate innovative formats and ways to reach their audiences in a world where social consumption with physical co-presence has suddenly become almost impossible.

Over the course of 2021, the Metaverse will experience widespread use, and start to become a human co-experience utility. People will meet in virtual worlds not just to play a game, but also to check out a new movie trailer or laugh at user-generated videos. Education will move from learning to code online to learning core sciences with physics or biology simulations and ultimately becoming an immersive environment where classrooms are organised within it. Some might have fun recreating familiar physical locations, such as their university campus or their company's HQ, where they can meet with colleagues working remotely.

We will see an increase in the creation of these massive, immersive virtual events in 2021. As the technical capabilities of the Metaverse expands, it will become possible for thousands of people to witness these events at the same time. These will push the boundaries of interactivity, where artists and fans converge to create new kinds of live experiences. Out of this, novel forms of entertainment will emerge, creating new Metaverse stars and launching careers similar to the rise of social-media influencers.

The Metaverse will also enable remote work with 3D virtual meetings that support large companies and industry events, where one can watch presentations or network at a cocktail party. Creating together will also vastly expand in the Metaverse, from digital experiences, such as game design, to fashion and architecture.

The Metaverse is arguably as big a shift in online communication as the telephone or the internet. Within the next few decades its applications will exceed our wildest imaginations. Perhaps the greatest opportunity it presents is to bring together people from all walks of life and foster a civil digital society. In 2021, that new society will begin to emerge for real.

David Baszucki is an inventor and the CEO and Founder of Roblox

The same old expressions
There will be no new emoji released in 2021 – The Unicode Consortium, the group that sifts through submissions for new emoji, has pushed the release date back to 2022. The main reason seems to be that the volunteers the Consortium relies on have too much other work to do to create smileys.

Storytelling will make the leap to smartphones

The new format for fiction will be interactive and experienced through connected apps

By **Nihal Tharoor**

THE DOMINANT NARRATIVE MEDIUMS OF CINEMA, television and literature are ill-equipped to deal with a mobile-first ecosystem. To faithfully narrate our digital lives, we need a storytelling medium that reflects that interactive world of smartphones. In 2021, we will be engrossed in interactive, phone-based storytelling.

This will be an evolution of the non-interactive text stories offered by platforms such as Hooked, which has more than 100 million unique readers of its bite-sized narratives, and on stories drip-fed to users over a number of days by apps such as UNRD, in which actors are used to create the media on a user's phone.

Interactive story apps are also not new – both Episode and Choices have millions of daily users – however, the new wave of storytelling we'll see come to the fore in 2021 will embed interactivity within the tools on a user's phone.

German studio Everbyte and Malaysian studio Kaigan Games are two companies set to make ground in this space in 2021. Both are developing interactive thriller and horror series – *Duskwood* (Everbyte) and *Simulacra* (Kaigan) – that simulate apps on a phone to tell stories. British game designer Sam Barlow, creator of the acclaimed FMV narrative mysteries *Her Story* and *Telling Lies*, is also reported to be working on a new interactive project in this space.

My company, Electric Noir Studios, is part of this new wave. In our interactive crime series *Dead Man's Phone*, users are cast as detectives who investigate and solve murders through the victims' smartphones. In this way the player becomes the lead character in the drama and participates in the narrative. On their phone, they will have a news app that reports on who they arrest, a maps app where they can track the live location of suspects, a social media app where they can launch a viral campaign – and even a Zoom app to conduct remote police interviews.

The power-consumers in this emerging space are notably young women. Far from traditional mobile gamers, this audience are also big fans of true-crime podcasts, Netflix crime dramas and murder-mystery fiction and they see this new interactive media as an extension of that.

In 2021, through a mobile-first form of escapism, the boundary between the real-life apps on our phones and those involving us in an intriguing fictional world will blur.

Nihal Tharoor is co-founder and CEO of Electric Noir Studios

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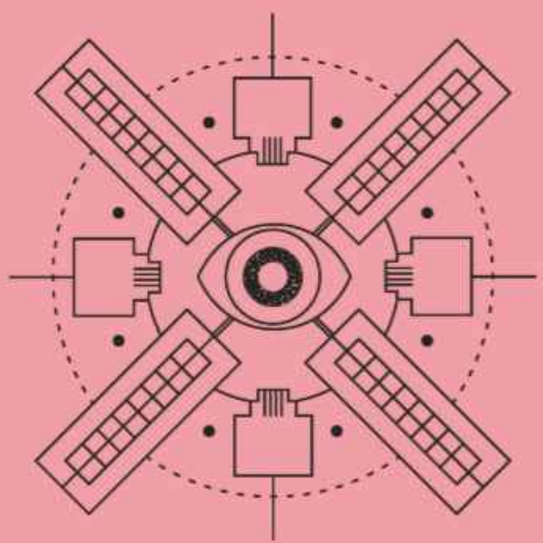

Security

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Global communication will be under threat

International squabbles will undermine the security and interoperability of technology

By **Ian Levy**

THE TECHNOLOGIES AND STANDARDS that underpin communication around the world are, for the most part, global and interoperable. From the microprocessor architectures that power everything we do, to the standards set by bodies such as the Internet Engineering Task Force, which oversees the way the internet works, and 3GPP, which has a similar role for mobile communications, we have developed an inexorable tendency to commonality. We all use Intel- and ARM-designed microprocessors in the devices we own. Our mobile phones can work pretty much anywhere on the planet. Transport Layer Security protects our online lives whatever browser we use and whatever service we are using – something that has been critical during the Covid-19 pandemic.

Common standards mean that designs can be checked once by all interested parties and having many different, interoperable implementations means that errors and vulnerabilities are likely to be caught early. From a cybersecurity point of view, this is good, as it has enabled us to secure systems at a scale that was previously impossible. No system is ever perfect, but making security open and a commodity is our best bet.

In 2021, we risk losing this advantage as we see the beginning of the balkanisation of technology and standards.

States compete and – as we now know – are increasingly weaponising information to gain advantage, breaking into other countries' networks to steal data, seed misinformation or disrupt infrastructure. But now we are seeing states use the development of and access to technology as tools of statecraft.

States don't like strategic dependence and so, in 2021, they will develop standards and technology that diverge from global commons, and which embody their values and which they control. This will be more than the different "flavours" of the internet we are already seeing emerge. It will be a fundamental shift in how technology is developed, owned, accessed and leveraged by nation states and companies.

In 2021, new alliances will form around the creation of indigenous and sovereign versions of the technology we use to communicate and manage modern life. We will see standards bodies fragment and supply chains and infrastructure redesigned to align with these new realities. States will start to take more drastic action to ensure that their supply chains are protected, and that their sovereign "silicon-to-service" technology stacks are insulated from the actions of others and enforce their national values.

The global debate around 5G security has led to a position where we will likely see two independent camps moving forward, ostensibly led by the US and China. They are likely to develop the standard in slightly different ways, driven by national requirements and values. China will accelerate its "Made in China 2025" strategy to ensure it owns and builds critical technologies. As a result, other nations will have to decide which camp better serves their national interest, since the only companies that produce this technology are bound to those countries. This will establish a pattern which will be repeated across other critical technologies.

The multi-stakeholder approach to standards that ensures no one party has too much power will be more critical than ever to ensure that we can continue to do cybersecurity at scale. But just as important is ensuring that there is a diverse set of companies that can provide these technologies, and that we continue to have interoperability. The UK's diversification strategy for telecoms is an example of the sort of intervention that will be needed. If we fail, the world will become less connected, less resilient and less secure.

Ian Levy is technical director of the UK's National Cyber Security Centre

Data will slow cyber attacks

Tactics from cybersecurity firms will influence 2021's business strategies

By **Claudia Natanson**

DURING 2020, INSTITUTIONS OF ALL kinds were forced to adapt to a dynamic world where the usual projections and five-year marketing plans did not apply. Economic reports show marked GDP reductions of greater than 20 per cent in many countries, with continued decline into 2021. Businesses and workplaces will increasingly turn to models of work in dynamic fields – such as cybersecurity – to make them more resilient.

Organisations that emerge out of the pandemic and the ensuing economic turmoil will have spent 2020 continually adapting to previously unimagined circumstances. This is a very familiar environment for people working in security, and particularly cybersecurity, because quite often we don't know what the next couple of hours will look like. Businesses of all kinds will discover the need to adopt fluid models and frameworks developed in a dynamic field and use them to redirect money, personnel and resources rapidly.

Typically, most businesses rely on static, predictive data analysis for growth and sustainability. They study insights and information from the previous few weeks and base predictions on them. However, these statistics can be rendered virtually useless within the next hour. Instead, businesses must start using data as they get it, proactively seeking out problems that could pose danger – just as cybersecurity specialists do.

Many cybersecurity frameworks can be modified to suit businesses more broadly. One example is data orchestration – where information that has been siloed in various parts of an organisation is collated and made available for rapid analysis. Another is the concept of common vulnerability exposures (CEVs). This is a standardised identifier for known vulnerabilities, such as a weakness in a certain kind of encryption or an exposure such as a large data breach in the last two years. Lists of these are available for any organisation looking to improve its cybersecurity. A version of this approach for other industries – known issues with certain suppliers, for example – could be used to make all kinds of firms more resilient.

In cybersecurity, we often take a three-pronged approach: detect what the potential threat is; take immediate action to protect information; and establish long-term defences to systems, such as new kinds of encryption. Businesses will find that adopting these processes and tools – especially their emphasis on the early detection of potential threats and the sharing of information when necessary – will help future-proof operations.

Early adopters will be the winners here. Workplaces and organisations that embrace the reality of a dynamic environment, rather than yearning for static working and legacy business models, will outperform their competitors. In 2021, companies and institutions that adopt principles such as data orchestration and CEVs, will find they're in a better position to survive.

Claudia Natanson is chief information security officer at Diageo

We'll build resilience in ourselves, our culture and our governments

By examining what we did wrong and right during the Covid crisis, we can change our mindset for the better

By **Stephanie Hare**

RESILIENCE IN PUBLIC HEALTH – UNTIL now seen as a cost to be minimised as much as possible – will be reframed as an investment in national security. Governments will lead the shift in mindset, but they need not shoulder the burden alone. The private sector and individuals also have a part to play.

This will require us to learn not only what went wrong in 2020, but what went right – not for reasons of blame, but for self-preservation. We may have to live with this virus for a long time, even indefinitely. Covid-19 exposed the fragility of how most of us have been living – and how vulnerable we are to further large-scale, multi-factor catastrophic events.

The pandemic has also revealed some exceptions to that trend which may help us rethink resilience. There was no panic-buying in Switzerland; Germany had enough hospital capacity to treat its own population and assist its neighbours; Denmark reopened its schools and Greece resumed its tourism industry and infection rates and death tolls in both stayed low.

These sound like fairy tales to anyone living in the US, Brazil, Mexico, the UK or India – the countries with the highest recorded numbers of deaths related to Covid-19 in 2020. But they are not; they are evidence. They demand we at least acknowledge that the high infection rates, heart-breaking death tolls and economic devastation were not inevitable. They suggest that something went wrong with many pandemic preparations and tabletop war games of the World Health Organization, national governments and companies. Nor is this unique to governments and institutions: for all the businesses that have struggled, collapsed, or just about survived, others have thrived.

To boost our resilience in 2021 we will improve our ability to anticipate risks and mitigate them. Can we pivot, repurpose and innovate? What is the speed, strength and depth of our ability to respond to a complex and potentially devastating event? How long can we last until we get things back up and running to the minimum viable level, and ultimately, to normal?

This will see us overhaul our pre-pandemic mindset, which considered the "just-in-case" model of spare capacity, reserves and preparedness to be "wasteful". We will admit that the just-in-time model of our global economy, though more profitable when everything is running relatively smoothly, is extremely fragile when it does not. It fails to thrive in resilience, which is, more often than not, measured by what did not happen thanks to prevention or mitigation, rather than what did. We will also reassess the ideologies, profit-seeking and short-term thinking that accompanies election cycles and quarterly earnings, which discourage countries and companies from improving their resilience – and penalise them when they do not.

In 2021 we will gain a new understanding of the truth of resilience: we are only as strong as our weakest link.

Stephanie Hare is a journalist specialising in technology, politics and history

Conspiracies will embrace alt-tech

Malevolent misinformation will find new outlets in 2021

By **Yasmin Green**

ONLINE CONSPIRACY THEORIES ARE surprisingly convincing – and present significant danger to the real world.

At Jigsaw, a division of Google focused on countering digital extremism, cyber attacks and misinformation, we conducted more than 70 in-depth interviews in 2020 with people in the US and UK who believe the Earth is flat, that school shootings were government plots and that white populations are being intentionally replaced by non-whites.

Those beliefs lead to changes in behaviour: we found that people who believe disinformation about the origin of Covid-19 shun face masks and ignore social-distancing. In 2021, anti-vaccination activists will use the internet to warn about what they see as nefarious motives behind any pandemic-vaccination programme.

Social-media platforms have now started to respond to Covid-related, racist and xenophobic conspiracy theories by removing content associated with these from their sites. This will protect unsuspecting people from stumbling across them. But the propaganda itself will not disappear. In 2021, these ideas will resurface on "alt-tech" networks such as Gab, Telegram and 8kun, platforms that market themselves as being "anti-censorship" (read: unmoderated) and for "free speech" (read: hate speech welcome). For the first time since the dawn of the social-media age, online content will go viral elsewhere.

Moving dangerous content into the "alt-tech" world will present two dangers. The first is that the inaccessibility of these subjects could encourage people to seek them out. Spreaders of conspiracy theories will have the opportunity to sensationalise a "censored" video ("what they don't want you to see") – what is known in online marketing as a "curiosity gap".

The second is that, ironically, the displacement of those ideas to more fringe platforms could help them spread, removing scepticism they may face from mainstream audiences. Our interviews with hardcore conspiracists revealed the need to signal in-group status by voicing agreement and even engaging in one-upmanship by expanding on the conspiracy.

In 2021, we may feel reassured that social media companies are taking on a limited role as moderators. However, it is likely that the narratives with the greatest potential to cause harm will thrive away from the major platforms and, similar to QAnon in the US, find alternative routes into mainstream consciousness. Just because we can't see them, won't mean that they don't continue to pose a threat.

Yasmin Green is director of research and development at Jigsaw, a division of Google

Democracies will fight back in the cyber wars

The US and UK will respond more robustly to interference from Russia and others

By **David Omand**

David Omand is visiting professor at King's College London, and a former UK Security and Intelligence Co-ordinator and director of GCHQ

RUSSIA HAS BECOME ADEPT AT USING cyber attacks and digital-media manipulation to influence events in other countries. We know there was Russian digital interference in the 2016 US general election and the 2017 presidential election in France: both involved fake social-media accounts and "hack-and-leak" operations to steal emails. The UK government has not investigated whether, as must be probable, Russia had also been using its tools of covert subversion during the Scottish independence and Brexit referenda, but it has said that it is almost certain that Russian actors sought to interfere in the 2019 general election through the online dissemination of illicitly acquired government documents, thought to relate to US/UK trade negotiations.

So far, the Kremlin seems to have come out of these actions unscathed, but in 2021 all that is likely to change. Behind the scenes, the US, UK and other Nato allies have been quietly regrouping in the face of Russian provocations and acquiring the means to defend themselves and democracy in cyberspace. The UK government has revealed that it is developing cyber weapons, and has successfully used offensive cyber techniques against the online propagandists of Isis. Joe Biden has said that, when he was vice president, he favoured developing cyber weapons, under the control of the US military's Cyber Command, the NSA and, in some circumstances, the CIA. During his presidential campaign, Biden has said that as president he would not hesitate to impose substantial and lasting costs, leveraging all appropriate instruments of national power including cyber responses, if the Kremlin does not halt its efforts to interfere in US democracy.

The allied objective will be deterrence by denial, raising the costs to the Russian attackers (including identifying the culprits by name) and reducing the value of expected gains. In 2021, we will have active cyber defences of government networks and those of critical national infrastructure to identify hostile penetration attempts. Work by major social-media platforms will enable illegal content and bogus accounts to be identified faster and taken down. The public will also be better informed about foreign interference. The task of the attackers will be complicated by the need to defend their own systems from counter-attacks and being fed cyber "poison pills". Russian attacks that cause collateral damage, as they did to the tune of more than $10 billion to global industrial corporations during the 2017 NotPetya attack on Ukraine (the most destructive and costly cyber attack in history) will also not go unpunished. Skirmishes in cyberspace will intensify in 2021 with pre-planned ambushes on the side of the attackers.

The hope must be that rather than protesting and admitting that their much-vaunted abilities in cyberspace are being countered, the Kremlin may tell its hacker communities to reduce their activities. But, if the Russian response is instead to escalate, what currently goes on in cyberspace in 2021 will not stay there. Vladimir Putin must know, for example, that what would hurt would be using western digital and human intelligence to expose his links to Russia's oligarchs and reveal financial holdings overseas. That really would be a counter-attack with a difference.

Cyber attacks are coming to space

Complex systems on Earth rely on the security of satellite networks, creating a new digital battlefront

By **Beyza Unal**

OUR INTERCONNECTED WORLD IS completely reliant on satellites. In 2021, there will be an increasing number of attempts by states and independent groups to mount cyber attacks on space infrastructure, with consequences for terrestrial systems.

In 2017, 20 ships in the Black Sea lost their ability to navigate due to a spoofing attack on their GPS systems, almost certainly carried out by Russia. In 2021, Russia will continue such attacks alongside the US, China and India, but they will also be joined by other nations, including Iran. Iran has targeted critical infrastructure in the past – in 2011 it hijacked a US drone by interfering with its navigation system – and since then it has been building its space capabilities.

Space is now so crowded that physical attacks on satellites risk the aggressor damaging their own assets at the same time. Instead, states are now considering cyber attacks to disable or diminish the capabilities of adversaries' satellites, targeting technology both in space and in ground stations.

Attacks will include jamming, spoofing or shutting down a unit entirely, changing its orbit or disabling components such as sensors. Other attacks in space will be aimed at gaining access to surveillance data and imagery. On the ground, attacks will be on control centres or servers containing data.

This will be a stealthy battleground. Space cyber attacks, unlike other types of counter-space weapons, come with a degree of deniability. Russia has still not acknowledged its alleged role in the 2017 shipping GPS incident, for example, although a year earlier it had said it was adding GPS jammers to more than 250,000 cell towers as a partial defence against a US cruise-missile attack. And, just like their terrestrial equivalents, cyber attacks exploit vulnerabilities that can be silently uncovered long before an actual attack takes place.

Defending against cyber attacks in space will involve comprehensive and ongoing iterative risk assessment. States will have to map out their critical networks and share threat intelligence with their allies. They will need to review the encryption protocols of their ground stations, and they will need to prepare their militaries and other essential sectors for the very real possibility of the loss of space services. Countries that are able to future-proof their space assets against emerging threats in this way are likely to be the ones that will prevail in what is rapidly becoming a new arena for conflict.

START will come to a stop
The New START (Strategic Arms Reduction Treaty) will expire in February 2021. Since 1972, it has limited the size of the US and Russia's nuclear arsenals. No extensions have been proposed, and there is not enough time (or political will) to renegotiate it.

Beyza Unal is a senior research fellow at Chatham House, the London -based think tank

Learn to expect ransomware – the tsunami is coming

Businesses will pay the price of intensified criminal attacks on infrastructure

By **Michael Sentonas**

Michael Sentonas is CTO of CrowdStrike

RANSOMWARE IS ONE OF THE FASTEST growing threats in cybersecurity, with global damages predicted to reach £15bn by 2021, up from £262m in 2015. Attackers will in 2021 target companies under pressure from the post-pandemic economic recession and they are more likely to cave to ransom demands.

Conventional ransomware attacks work by denying an organisation access to its own data until it pays a ransom. In 2020, however, we have seen attacks grow in sophistication. The developers of Maze ransomware, for example, have begun taking copies of data and threatening to release it publicly. Others, such as REvil, threaten to delete it entirely.

The business of ransomware is also changing. We are seeing actors ramping up demands – in some cases, seeking payment of one sum in five days, but then demanding more every few days after. Some groups charge an organisation to unlock access to its data, but also go on to sell data they have harvested, giving them a revenue "double dip". Attackers are also shrewd businesspeople, carefully pricing their demands so that paying them off is a rational, if unpleasant, commercial choice.

In 2021, we will see an increased trend away from a "spray and pray" approach to ransomware attacks to ones known as "big-game hunting". This is where attackers focus their efforts on victims that can yield a greater financial pay-off. There will be bold cyber strikes on wealthy organisations by major e-crime organisations (known as "SPIDERS"). These include INDRIK SPIDER, which runs Dridex, and WIZARD SPIDER, the Russian-based operator behind the TrickBot banking malware and Ryuk. Groups such as these have already seen huge revenues from ransomware attacks. WIZARD SPIDER is thought to have netted around 695.80 Bitcoin, with an approximate value of £2.7m, since 2018. Meanwhile, the BOSS SPIDER group, thought to be based in Iran, received more than $6.7 million (£5.1 million) between 2016 to 2018.

In 2021, organisations will become more vulnerable to attacks because many of their employees will be using home internet connections, many of which are far less protected than corporate networks. This will increase the chances of actors gaining entry to an organisation's systems, but it also raises questions of liability. Who is responsible if someone's home network is taken out as collateral damage during an enterprise hack? In 2021, we will all have to agree that "everything this side of the firewall is the business' responsibility".

While 2021 will be a boom time for ransomware attackers, solutions such as cloud-delivered, AI-driven security that can react in real time will help us defend ourselves against them. But all enterprises will also have to look hard at their cybersecurity measures and understand that "good-enough security" isn't good enough at all.

Colophon

Many thanks to all the writers, illustrators, photographers, predictors, analysts and influencers whose contributions made The WIRED World in 2021 possible...

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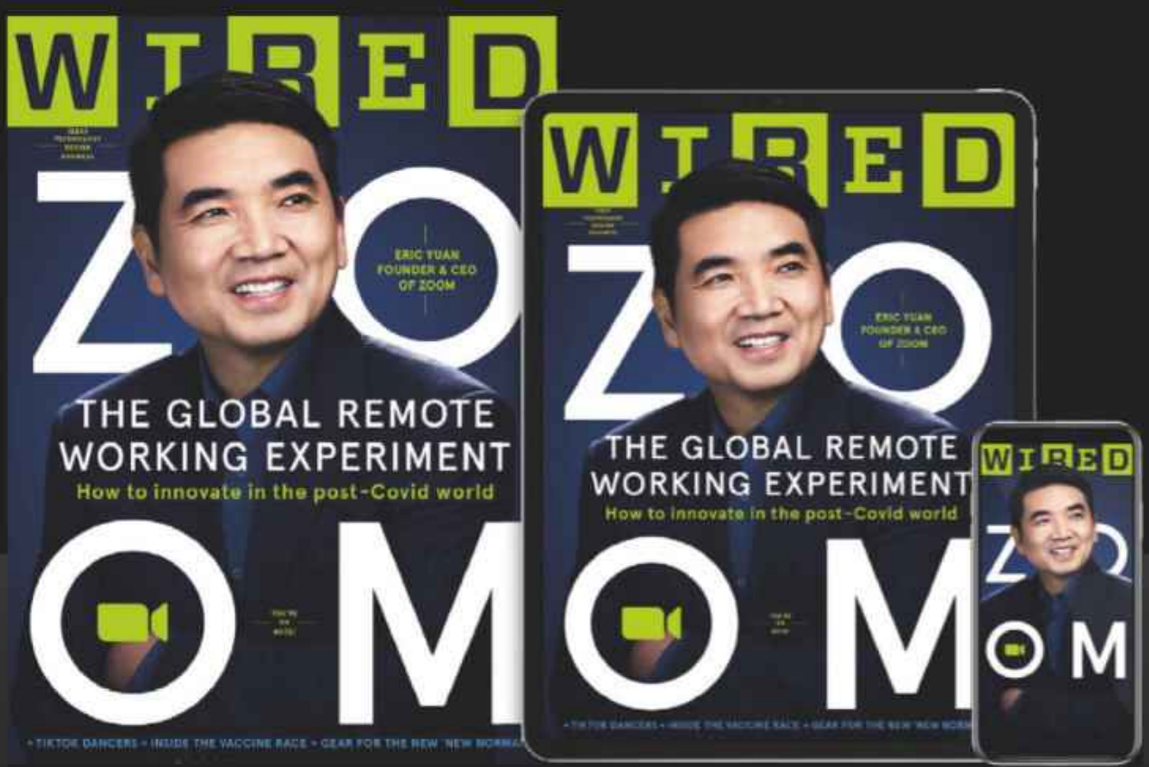

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